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VOLUME 31 MAY, 1957 NUMBER 3

LATE MISSISSIPPIAN FAUNA FROM THE REDOAK HOLLOW FORMATION OF SOUTHERN OKLAHOMA

PART II. BRACHIOPODA

MAXIM K. ELIAS
University of Nebraska

ABSTRACT—Thirty species and varieties of corneous and calcareous brachiopods are described, twelve new. Fragmentary material indicates possible presence of two undescribed new genera. Status of genus *Diaphragmus* and its generotype is analyzed. Malformations in brachiopods are described and discussed. Great majority of described brachiopods indicate late Mississippian age, but a few are identical with the Morrow forms *Meekella striatocostata* and *Punctospirifer kentuckiensis*.

BRACHIOPODA

LINGULA sp. cf. L. PARACLETUS Hall and Clarke

Pl. 51, fig. 1,2

1892. *Lingula paracletus*, HALL AND CLARKE, N. Y. Geol. Survey, Pal., vol. 8, pt. 1, p. 172; p. 12, fig. 8.
1895. *Lingula paracletus*, HALL, N. Y. State Museum, 48th Ann. Rept., vol. 2, (also N. Y. State Geol. 14th Rept.) p. 326, fig. 1.
1909. *Lingula paracletus*, GIRTY, U. S. Geol. Survey Bull. 377, p. 15–17; pl. 1, fig. 1–5.

Description.—The single specimen found in the Redoak Hollow is a nearly complete valve with its outer part exposed. It is 17 mm. long and 12 mm. wide, which indicates ratio of width to length about 1:1.42, which is very close to the average of the ratio established by Girty for this species. The form is classified as *L.* cf. *paracletus* only because the structure of the inner side of the valve is unknown, while that of *L. paracletus* is.

Discussion.—Thanks to Girty's painstaking work on *Lingula* and related genera from the Mississippian and Lower Pennsylvanian of the Midcontinent, it is possible to identify the form from the Redoak Hollow with *L. paracletus* from the Caney rather than with the closely related *L. batesvillae* Girty from the Batesville. Girty (1911, p. 36) points out that *L. batesvillae* "in specimens of the same size possessed of a considerably different shape, which is relatively narrower and less ovate" than in *L. paracletus*. According to Girty's statements on the proportions of width to length in these shells, he states that in *L. batesvillae* "Length is to the width as proportion of 3 to 2, varying to the proportion of 5 to 3" (ibid., p. 32); in *L. paracletus* from the Caney "the length varies from one and one-half to one and one-third times the greatest width" (Girty, 1909, p. 15). Bringing these data to a common denominator the following table for the ratio of width to length in these species may be construed:

For *L. paracletus*—1:1.5 to 1:1.3
For *L. batesvillae*—1:1.7 to 1:1.5

Mather (1915) found no *Lingula* in the upper Morrow of Arkansas and Oklahoma, and neither did Girty and Roundy (1923) in the equivalent beds of the Ardmore Basin (see in Tomlinson, 1929, p. 74–76).

The nearest form to *Lingula paracletus* in higher beds of the lower Pennsylvanian is *Lingula carbonaria* Shumard in a broad sense of this species. Although in most occurrences this form is substantially smaller than the species from the Caney and the Redoak Hollow, Girty (1915, p. 49) describes briefly (but does not illustrate) a specimen of *Lingula* from the Wewoka of Oklahoma, which is 18 mm. long. He states that it has "almost the same size and very nearly the same proportions as the largest Meek and Worthen's figures," (1873, pl. 25, figure 2b) which "may be an enlargement of one of their smaller illustrations." My measurement of the width and length of figure 2b by Meek and Worthen (1873, pl. XXV, fig. 2a-c) indicates proportion 1:1.46 (13 mm. ×19 mm.), which is within the variability of the ratio established for *L. paracletus* by Girty. Girty (1915) does not comparatively discuss this species and *L. carbonaria*, but judging by the most accurate illustrations of *L. carbonaria* by Meek and Worthen (1873, pl. XXV, fig. 2a-c), and by Dunbar and Condra (1932, pl. 1, fig. 1,2) this species has a much more acute posterior end, its slopes nearest the beak being straight to even slightly concave (in Meek and Worthen's examples), while in *L. paracletus* the posterior is rounded.

Genus CRANIA Retzius

1871. *Crania*, RETZIUS, Schrift. Ges. Naturf. Freuende, Berlin, vol. 2, p. 72.
1892. *Crania*, HALL AND CLARKE, N. Y. Pal., pt. 1, p. 145.
1914. *Crania*, WELLER, Ill. Geol. Survey, Monograph 1, p. 43.
1932. *Crania*, DUNBAR AND CONDRA, Nebr. Geol. Survey Second Ser., Bull. 5, p. 50–51.

Genus *Crania* was established on a living form, *Anomia craniolaris* Linné serving as genero-lectotype. For practical recognition of the genus on the fossil material, particularly from the late Paleozoic rocks, some guidance is given in the diagnosis of the genus formulated by Weller (1914), and Dunbar and Condra (1932). According to Weller (1914, p. 43) the most critical feature in differentiating the branchial (conical) valves of *Crania* from those of the very similar genus *Orbiculoidea* (= *Lingulodiscina* of authors) is "more nearly central position of the apex and its more erect position" in *Crania*. By this is meant the tendency of the apex or beak in the brachial valve of *Orbiculoidea* to be curved toward the posterior margin and assume a position less than $\frac{1}{3}$ (in my observation) of the diameter from this margin. In *Crania* the apex shows no definite inclination in any direction and does not seem to depart from central position farther than $\frac{1}{4}$ of the diameter, that is its distance from the posterior margin is more than $\frac{1}{3}$ of the diameter (my observation).

Weller gives a further hint for differentiating *Crania* from *Orbiculoidea* by remarking that the brachial valves "of the two genera also may be commonly differentiated by reason of the less regular manner of growth in the genus *Crania*." That is, the outline of the shell in *Crania* is frequently somewhat irregular, while in *Orbiculoidea* it is more nearly geometrically regular.

Dunbar and Condra (1932, p. 50) state that the outline of the dorsal (brachial) valve of *Crania* is "subcircular to subrectangular," and that the posterior margin is "straight or slightly indented," and its shell is "calcareous and punctate." They also state that its ventral valve is "cemented by almost its entire surface, and lacking a pedicle opening."

CRANIA MINUTA, n. sp.
Pl. 51, fig. 14a

Description.—The species is based on a single, very small dorsal valve attached to the outer surface of a dorsal valve of *Chonetes kingi*. The shell is quite circular. Its beak is located eccentrically, at a distance from the edge about $\frac{1}{3}$ or slightly more of the diameter of the shell. The dimensions are as follows: diameter 1.2 mm. and the height of the valve about .3 mm. Ventral valve unknown, probably destroyed together with the shell of *Chonetes* to which it undoubtedly tightly adhered.

The form if accepted as a full grown individual is apparently the smallest among the known species of the genus.

Because of complete destruction of the substance of the valve, only the external

mold of which is preserved, it is impossible to ascertain whether it was calcareous or chitinous, but since a valve of *Lingula* was found in the same rock with its chitinous substance fully intact, while all calcareous shells in the same rock are usually completely dissolved, it seems more likely that the substance of the described species was calcareous. The fact that its ventral valve apparently has been fused to the shell of *Chonetes*, and its apex has subcentral position in the dorsal valve is also typical for genus *Crania*.

Discussion.—The previously known species of *Crania* in the upper Mississippian and Lower Pennsylvanian rocks, which are nearest to *C. minuta*, are *C. chesterensis* Miller and Gurley from the Chester series and *C. modesta* White and St. John from the Pennsylvanian system. *C. chesterenesis* is the smallest among the species known from the upper Mississippian of America, its diameter being 7×8 mm., but Girty (1915, p. 40) records *Crania* sp. from the Batesville sandstone of Arkansas whose diameter is only 5 mm. According to Girty (1915, p. 53–54) *Crania modesta* is up to 12 mm. in diameter. None of the published illustrations or descriptions of either *C. chesterensis* or *C. modesta* record sufficiently small shells that approach the minute size of *C. minuta* here described.

The smaller the individual of the two former species the flatter their dorsal valve, while the dorsal valve of *C. minuta* stands out in bold conical relief above the surface of attachment, its conical shape reminiscent of that in *Orbiculoidea*. Doubtlessly it does represent a new, minute species of *Crania*, and not a young of the previously known small species of the genus. In the departure of its apex from the central position it seems to stand nearer to some of the examples of *C. chesterensis* illustrated by Weller (1914, pl. 1, fig. 27–29) than those illustrated for *C. modesta* (Girty, 1915, pl. VI, fig. 12–14; Dunbar and Condra, 1932, pl. 1, fig. 23–25).

ORTHOTETES-DERBYIA group

In a comprehensive summary of the phylogeny of Orthotetinae Dunbar and Condra (1932, p. 73–75), briefly characterize the evolutionary change from *Orthotetes* to *Derbyia* thus:

> In "the Devonian and Lower Carboniferous genus *Orthotetes*, . . . a median ventral septum is developed and the short dental lamellae converge to form a small spondylium under the deltidium. About the beginning of Pennsylvanian time, the dental lamellae in this stock underwent a rapid reduction, the spondylium being gradually shortened to disappearance as *Orthotetes* gave way to *Derbyia* on one hand and *Derbyoides* on the other."

In the diagram of the phylogeny (ibid., fig. 2, p. 73) the described change is graphically illustrated, and the stratigraphic point of change from *Orthotetes* to *Derbyia* is indicated by an abrupt end of the first genus and the beginning of the second at a horizon just below the Mississippian-Pennsylvanian boundary, even though, according to the text (quoted above) the horizon of the change should be placed above this boundary. This small discrepancy is of no import, because, in fact, there seems to be no abrupt change from one genus to another, and the trend from *Orthotetes* toward *Derbyia* apparently got started long before the beginning of Pennsylvanian time.

The evolutionary change from *Orthotetes* to *Derbyia*, in the sense so well formulated by Dunbar and Condra, has been previously well detected and described by Girty on the material from the Batesville sandstone of Arkansas, that is from the lower Meramec of the Mississippian. Girty placed the form with an initial development of the derbyoid characters in the genus *Orthotetes*, and described it as *O. subglobosus* var. *batesvillensis* (1915, p. 42–44, pl. 1, fig. 1–5). However, he admitted uncertainty of his choice of generic affiliation between *Derbyia* and *Orthotetes*, and gave the following analysis of morphologic variability that creates this taxonomic uncertainty.

> . . . I have never been entirely satisfied that both these groups (*Derbyia* and *Orthotetes*) should be regarded as valid genera. It will be recalled that Waagen, who proposed the name *Derbyia*, recognized them only as different manifestations of the same generic type. Where characteristically developed, these two types of structure appear distinct enough, but there are many species which are not typical. The present variety is one of these. Here the dental plates are short and the posterior edge of the septum passes obliquely forward from the apex. Thus, the three plates approach each

> other closely enough to form the characteristic structure for only a short distance. It would evidently be difficult to ascertain whether the plates met near the apex to form a Y-shaped figure with the septum, or passed on either side of the septum without uniting with it, and in the present case the difficulty is enhanced by the fact that they are more or less completely fused in an apical callosity. Among the specimens before me some seem to give evidence of an incipient camerate structure, where they emerge from the callosity, but others seem at least to show indications of the other types, through the septum projecting, for a very short distance it is true, between the edges of the dental lamellae without uniting them (Girty, 1915, p. 43–44).

We have a number of internal and external molds of separated ventral and dorsal valves from the Redoak Hollow, which undoubtedly belong to subfamily Orthotetinae, and though the molds are roughly imprinted in the sandstone, they show distinctly the same variability of the dental apparatus, as noticed by Girty, in the material from the Batesville. The orthotetid camerate structure or spondylium is only rarely and faintly indicated, and the typical derbyoid reduction of the apparatus to a simple median plate prevails.

Mather identifies with *Orthotetes* Hall the orthotetid shells from the upper Morrow, basing his specific, and particularly, generic identification on the observed "high cardinal area, the vertically elongated delthyrium closed by the convex deltidium, and the median septum typical of the species" (Mather, 1915, p. 147), but he neither describes nor illustrates the orthotetid spondylium. Girty identifies *Derbyia* n. sp. in the Otterville of Ardmore Basin (Tomlinson, 1929, p. 74), having no doubt about its derbyoid character. Dunbar and Condra (1932, p. 112–114) revised *Derbyia robusta* Hall and found that only some of the specimens illustrated in Hall and Clarke, 1892, are identical with the original material, as published by Hall, 1882 (1883), pl. (10) 40, fig. 12–16. Trusting the correctness of Hall's interpretation of the cardinal process in this species, they leave it in the genus *Derbyia*. They make no comments on Mather's identification of this species in the upper Morrow, and do not place the form described by him in their synonymy of the species. It seems that in size, shape and ornamentation, as far as can be observed on Mather's photographs, his material is fairly close to *O. batesvillensis* Girty, but Mather's form has a much higher cardinal area and on this ground possibly could be treated as a new variety. In the collection at the Nebraska Geological Survey from a sandstone ledge in the Hale shale at Hale Mountain, near Fayetteville, Arkansas, there are numerous molds of a fairly typical *Orthotetes batesvillensis*, which has the same intermediate cardinal structure as observed in the shells from the Redoak Hollow.

Hernon identifies *Orthotetes kaskaskiensis* (1935, p. 678) in the Paradise formation of Arizona, but finds that "some specimens approach the genus *Derbyia* in the relation of dental plate to the median septum."

The quoted and discussed facts seem to indicate that the late Mississippian forms of *Orthotetes*, which attain a stage transitional to *Derbyia*, should be in some way distinguished taxonomically. It does not seem advisable to treat them as a new genus

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EXPLANATION OF PLATE 51

FIG. *1,2*—*Lingula* cf. *paracletus* Hall and Clark, dorsal or ventral valve. *1*, side view; *2*, external view, ×2.

3–5—*Orthotetes* (*-Derbyia*) *kaskaskiensis* Weller. Inner molds of fragmentary ventral valve. *3,4*, ×1: *5*, ×2.

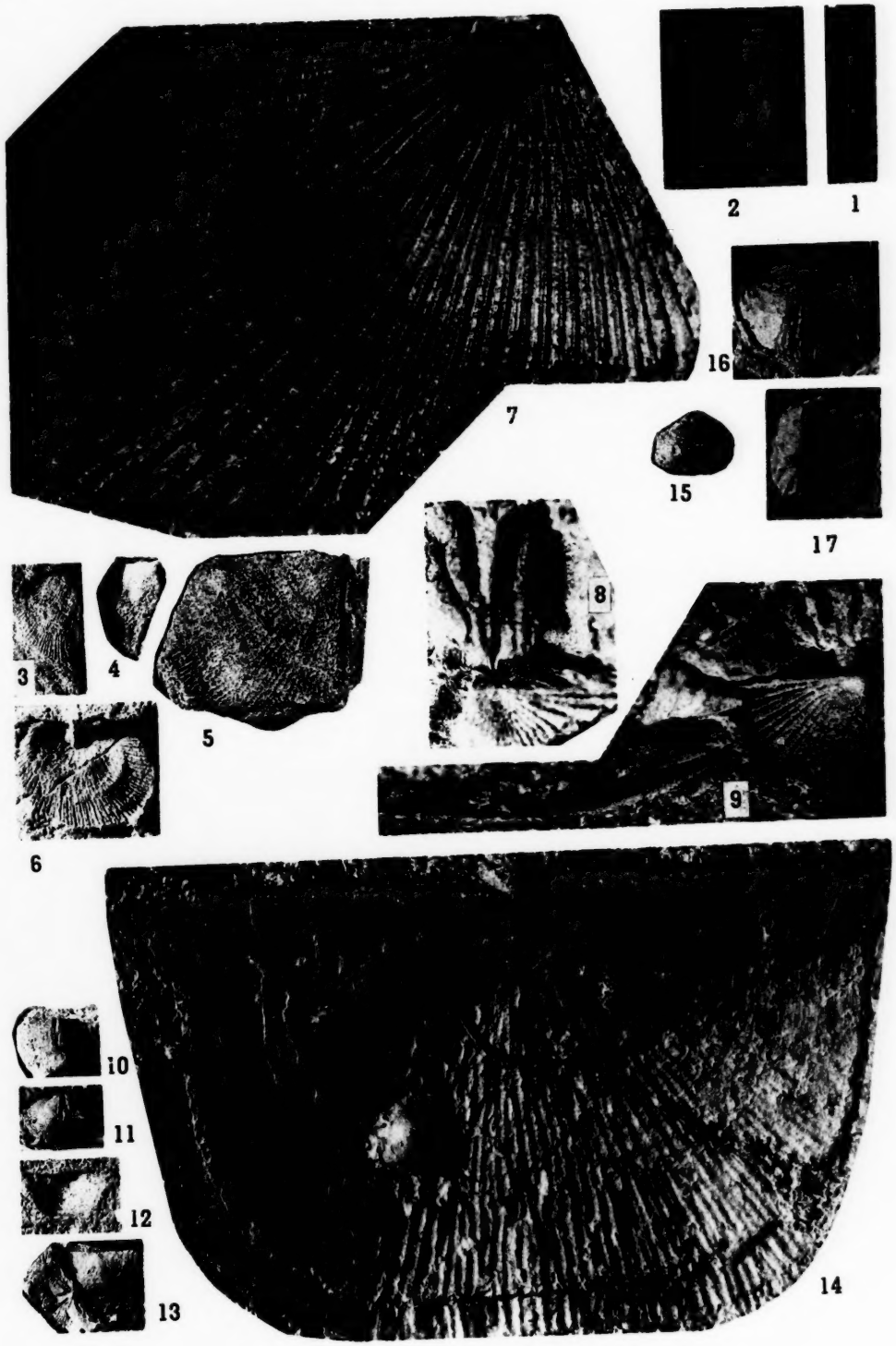
6,7—*Orthotetes* (*-Derbyia*) *springerensis*, n. sp. *6*, inner mold of ventral valve (paratype), ×1; *7*, outer mold of dorsal valve (holotype), ×10.

8,9—New genus aff. *Derbyoides* Dunbar and Condra. Outer molds of the cardinal process; *8*, holotype, and *9*, paratype, ×10.

10–14—*Chonetes kingi*, n. sp. *10,11*, inner molds of ventral valve, ×1; *12*, outer mold of ventral valve, ×1; *13*, outer mold of ventral valve, less convex than usual (upper right), and inner mold of dorsal valve (lower left), ×1; *14*, outer mold of dorsal valve (holotype), ×10.

15–17—*Cancrinella boonensis* (Swallow). *15,16*, inner molds of ventral valves; *15*, ×1; *16*, ×2. *17*, outer mold of ventral valve, ×2.

14a—*Crania minuta*, n. sp., inner mold of dorsal valve. Attached to outer side of dorsal valve of *Chonetes kingi*, n. sp., ×10.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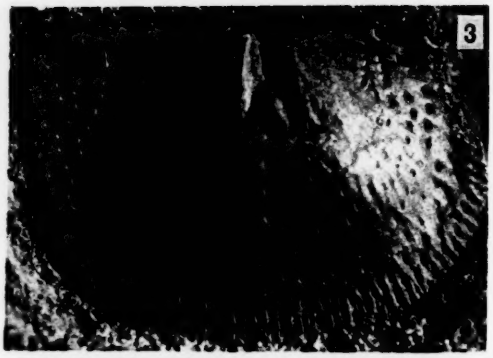
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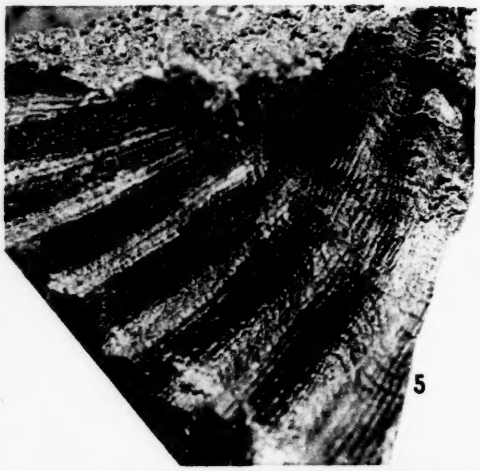
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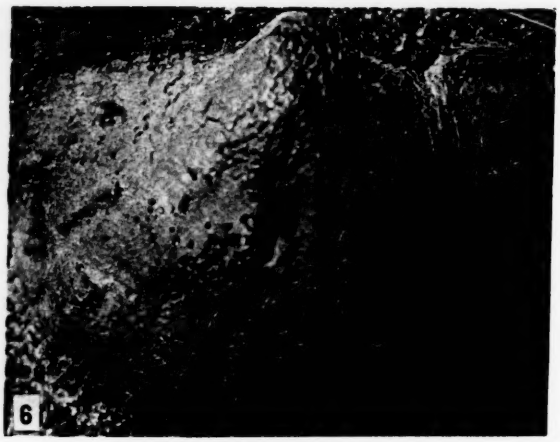
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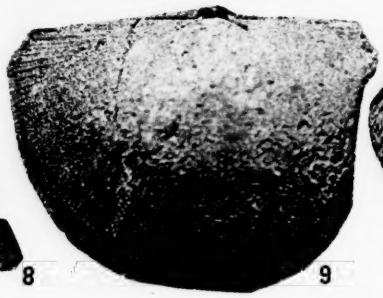
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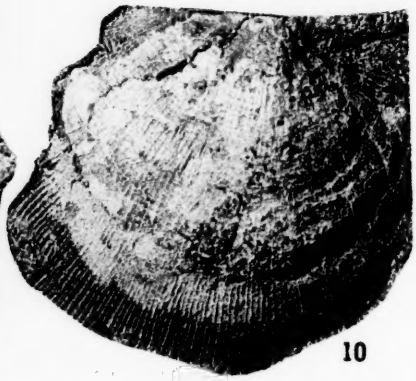
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TABLE 1—PRINCIPAL DIMENSIONS MEASURED ON INDIVIDUAL VALVES OF THE DISCUSSED SPECIES OF *Orthotetes* (*-Derbyia*)

Species and Occurrence	Length		Greatest width	Hinge line	Height of cardinal area	Convexity of ventral valve	Costae per 5 mm.
	Ventral valve	Dorsal valve					
O. robusta Mather U. Morrow, Arkansas)	40		52				
		38	63				
O. (*-D*) *springerensis*, n.sp. (Hale shale, Ark.; measured by the author)	21		28.5		5		9–10
	19		27		4.5		
		16	30				
	24		36				
O. (*-D*) *kaskaskiensis*, (Redoak Hollow fm., Ardm., measured by the author)		27	35				12
	20		25				11
O. kaskaskiensis, Weller, (Chester ser., Illinois)	41	37.7	49.5	35.5	9	19.5	12–13
	28.3	25.2	34.8	28.5	5.6	14	
O. kaskaskiensis, Butts (Chester ser.)							
fig. 1	33		47				
fig. 2	21.5		31				
fig. 3	17.5		26				
O. sublobosus var. *batesvillensis*, Girty (Batesville ss., Ark.)							
fig. 5	37		55	41.5			
fig. 1		37	52.5	43			
fig. 3		14.5	28–29	20			

transitional between *Orthotetes* and *Derbyia* because the extreme individual variations within such a genus would be impossible to distinguish from *Orthotetes* on one hand, and from *Derbyia* on the other. Because it is permissible, under the Rules of Zoological Nomenclature, to regard *Derbyia* as a subgenus of *Orthotetes*, the transitional forms can be designated, by adding the name *Derbyia* in brackets and adding hyphen, see discussion in the chapter on Taxonomy. This treatment of *Derbyia*, as a subgenus of *Orthotetes*, does not need to be expanded to the higher Pennsylvanian forms, whose derbyoid character is fully realized and stabilized. Adoption of such slightly modified usage of a name in the subgeneric sense is an expedient that does not seem to violate the existing Rules, while it seems justified by the phylogenetic and stratigraphic advantage of being a special kind of designation for the transitional forms (between

EXPLANATION OF PLATE 52

FIG. *1–3—Chonetes kingi*, n. sp. *1*, inner mold of hinge of ventral valve showing cardinal area and inner canals of spines, eight on each side from the center, ×20; *2*, inner mold of dorsal valve showing cardinal area, ×10; *3*, inner mold of young ventral valve, showing wide and short septum diverging into two short lateral branches and a longer but narrow and inconspicuous medial branch, ×10.

4—Chonetes sp. Inner mold of fragmentary ventral valve whose length is greater in proportion to width than in *Chonetes kingi*, n. sp.

5—Meekella striatocostata (Cox). Outer mold of fragmentary ventral valve. ×10. Note similarity of sculpture to that in *Spirifer casteri*, n. sp. (pl. 19, fig. 9: and other figures on pl. 1,2, and 4, part 1).

6—Productella recensis, n. sp. Inner mold of ventral valve (holotype), ×10.

7–10—Orthotetes (*-Derbyia*) *kaskaskiensis* Weller. *7,8* inner molds of cardinal area of ventral valve, ×2; *9*, inner mold of nearly complete ventral valve, ×2, *10*, outer mold of the largest ventral valve, ×2.

Orthotetes and *Derbyia*), which occur in the wide stratigraphic zone: from Meramec of the Mississippian almost to the Morrow of the Pennsylvanian.

ORTHOTETES (-DERBYIA) SPRINGERENSIS, n. sp.
Pl. 51, fig. 6,7

Description.—Three dorsal valves of this species have been recovered. They are of about the same size as the shells of *O.* (*D.*) *kaskaskiensis* from the same collection, but are proportionally wider, the ratio of length to width being about 3:5. In this respect the shells are like those of *O. subglobosus* var. *batesvillensis* Girty, but they are smaller and have coarser costae. The three dorsal valves measure 20, 15, and 13.5 mm. long, and 33, 23, and 21 mm. wide. The radiating costae number 8 to 10 per 5 mm. at a distance of 15 mm. from the beak, while the costae in Girty's form from the Batesville number 13 to 16 per 5 mm. at the same distance (counted on pl. 1, fig. 5, Girty, 1915).

No ventral valves have been found in the material from the Redoak Hollow, but in the collection at the Nebraska GeologicalSurvey from a sandstone ledge in Hale shale at Hale Mountain near Fayetteville, Arkansas, there are abundant examples of ventral (and also dorsal) valves, which are identical with *O.* (*-D.*) *springerensis*. Three ventral valves from this collection measure 24, 21, and 19 mm. long, and 36, 28.5, and 27 mm, wide, that is, their length to width ratio varies from 2:3 to 3:4; and one dorsal valve measures 16 mm. long and 30 mm. wide, a ratio much different from that in *O.* (*D.*) *springerensis* from the Redoak Hollow, and even nearer to that in *O. subglobosus* var. *batesvillensis*. The number of radial costae is about 9 or 10 per 5 mm. Height of cardinal area in the two smaller ventral valves 5 and 4.5 mm.

Discussion.—Radial costae in the examples from the Redoak Hollow and the Hale are of the same unequal character. Usually every other costae is narrower and lower, but occasionally the neighboring costae become subequal to equal on some parts of a valve. In this respect *O.* (*D.*) *springerensis* is unlike *O. subglobosus* var. *batesvillensis*, whose costae seem to be largely equal or subequal.

Cardinal area in the ventral valves from the Hale bears the same intermediate character between *Orthotetes* and *Derbyia* as that in the shell of *O.* (*-D.*) *kaskaskiensis* from the Redoak Hollow, hence the species is here classified in the intermediate *Orthotetes* (*-Derbyia*) group.

ORTHOTETES (-DERBYIA) KASKASKIENSIS Weller
Pl. 51, fig. 3–5; Pl. 52, fig. 7–10

1860. *Orthis kaskaskiensis* MCCHESNEY, Desc. New Pal. foss., p. 31.
1892. *Derbyic kaskaskiensis*. HALL AND CLARKE, N. Y. Pal., vol. 8, pt. 1, pl. 11B, fig. 6.
1914. *Orthotetes kaskaskiensis*. WELLER, Ill. Geol. Survey, Mon. 1, p. 77–78, pl. VI, fig. 1–14.
1932. *Orthotetes kaskaskiensis*. WELLER, Ky. Geol. Survey, Pal. of Kentucky (Symposium), pl. XLII, fig. 10a,b (reproduced from WELLER 1914, fig. 9 and 10)
not 1926. *Orthotetes kaskaskiensis*. BUTTS, Ala. Geol. Survey, Sp. Rep. No. 14, pl. 61, fig. 1–3.

Description.—A few ventral and dorsal valves from the Redoak Hollow can be assigned to this species with considerable confidence. They are of the same normal moderate size as most of the specimens illustrated by Weller (1914), and approach them closely in shape and sculpture. The shell of *O. kaskaskiensis* is only slightly wider than high, the proportion of length to width in ventral and dorsal valves being close to 4:5 and 3:4 correspondingly, as can be ascertained from the dimensions given by Weller (1914, p. 77) or measured on his photographs. In the nearly complete ventral and dorsal valves from the Redoak Hollow the length is 27 mm. and 20 mm. and the width 35 mm. and 25 mm. respectively. Weller (1914, p. 78) states that "From two to three costae occupy the space of 1 mm., the intercostal spaces usually being a little broader than the costae." In the form from the Redoak Hollow about 11 to 12 costae can be counted per 5 mm. near the anterior edge of the shell. The character of the costae is also the same, and so are the fine lines of growth that are altered into regular wrinkles in some areas, which combine with costae to produce reticulate sculpture.

The ventral valves display cardinal areas transitional between *Orthotetes* and *Derbyia*, (see the discussion in the preceding *Orthotetes-Derbyia* description).

Measurements of discussed species entered in Table 1.

? New genus, aff. DERBYOIDES Dunbar and Condra
Pl. 51, fig. 8,9

The evidence for a new genus is suggested by the discovery of a new type of cardinal process connected with an orthotetinid shell, but a formal name for it is not introduced because of incomplete material available on the shape of dorsal and ventral valves, and, particularly, because internal character of the latter is unknown.

The described cardinal process is in the form of a posterior mold attached to an apical portion of an outer mold of the dorsal valve. It is reminiscent of the cardinal process and adjacent hinge in *Derbyoides nebrascensis* Dunbar and Condra (1932, p. 115, pl. XIV; particularly fig. 3a), as its crural plates spread laterally, and, together with the cardinal process, build a broad structure. In the new genus this structure undoubtedly extends much farther into the umbo of the ventral valve than in *Derbyoides*, and is supported by a more massive base which apparently adheres closely to the broad deltidium of the ventral valve, while its base assumes nearly the same flattened sub-triangular shape as in the latter. This broadly sub-triangular flange-like base is characteristically coarsely striated by a series of uneven grooves, that arch steeply toward the center, but subside again when they are near it, so that a central sinus divides the lines into two symmetrical lateral arches (pl. 13, fig. 8). The broad crural plates are like those in *Derbyoides*, but extend much further forward as they fuse imperceptibly into the very large cardinal process, which is built somewhat like that in *Derbyia cymbula* Hall and Clark (see Dunbar and Condra, 1932, pl. IX, fig. 1c). Dunbar and Condra mention the unusually strong forward development of the cardinal process in *D. cymbula*, with its "crural lamellae extending vertically far out into the valve instead of being recurved toward the hinge-line" (ibid., p. 101). Close adherence of the base of the cardinal process against the deltidium in *D. cymbula* (ibid., p. 98) is also similar to the form from the Redoak Hollow. Perhaps the described form is ancestral to *D. cymbula*, and both belong to a new genus, or a subgenus, closely related to *Derbyia* and *Orthotetes*.

It seems likely that a fragment of an unusually convex ventral orthotetid valve belongs to this new form.

MEEKELLA STRIATOCOSTATA (Cox)
Pl. 52, fig. 5

1857. *Plicatulo striato-costata*. COX, Owen's Geol. Report, Ky., vol. 3, p. 568, pl. VIII, fig. 7.
1872. *Meekella striato-costata*. MEEK, Final Report U. S. Geol. Survey Nebr., p. 175–177, pl. V, fig. 12a-c.
For complete pre-1897 synonymy see Schuchert, U. S. Geol. Survey, Bull. 87, p. 264–265)
1900. *Meekella striatocostata*. GIRTY, U. S. Geol. Survey Bull. 384, p. 54, pl. 6, fig. 6.
1909. *Meekella striatocostata*, Girty, U. S. Geol. Survey Bull. No. 389, p. 54; Pl. 6, fig. 6.
1915. *Meekella striatocostata*, Mather, Denison Univ. Sci. Lab. Bull. v. 18, Art. 3, p. 148–149, Pl. X, fig. 1.
1932. *Meekella striatocostata*, Dunbar and Condra, Nebr. Geol. Survey, 2nd Ser., Bull. 5, p. 125–129, pl. XVI, fig. 1–10; Pl. XVII, fig. 3a–c.

Only one small fragment of an external mold of a ventral valve has been found, but its shape and sculpture are so typical for the species that it seems possible to make the identification with considerable assurance. This discovery supports, indirectly, the previous identification of *M. striatocostata* in the upper Morrow of Arkansas by Mather (1915), also made on only one incomplete ventral valve. The present identification lowers the known range of *Meekella striatocostata* down to the Redoak Hollow, but the species seems very rare both in it and in the upper Morrow.

The fragment from the Redoak Hollow seems to belong to a smaller than average example of the species, certainly much smaller than the "above the average specimen" illustrated by Mather (1915, pl. X, fig. 10). It has well preserved reticulate sculpture superimposed over a series of plications, a typical external appearance for a valve of *M. striatocostata*. This pattern imitates that of *Spirifer casteri*, even to the presence of the mucros at the intersection of the sharply elevated concentric and radial lines; thus the present fragment could be easily mistaken for the latter species, if it were not for the presence of pronounced and irregularly spaced transverse wrinkles, accompanied by localized interruption of the

radial plications. This peculiarity is occasionally observed in the posterior of the ventral valve in *M. striatocostata*, but is unknown in *S. casteri*.

CHONETES KINGI, n. sp.
Pl. 51, fig. 10–14; Pl. 52, fig. 1–3

1956A. *Chonetes kingi* (nomen nudum), ELIAS, Jour. Pal., v. 31, p. 379, pl. 39, fig. 3–7.

Description.—Abundant detached ventral and dorsal valves were found, their spines nearly always fully broken off. Adult shells up to 17 mm. wide and 9.5 mm. high, form ratio varying from 1.75:1 to 1.90:1. Convexity of ventral valve abt. 2.5–3 mm., but living space is not more than 1 mm. clearance, because dorsal valve is concave. Sinus slightly indicated in the anterior of some shells. Shell widest at hinge, usually with flattened auricle-like extensions, in front of which the shell decreases in width very gradually. Beak of ventral valve rises slightly above hinge.

External sculpture consists of distinct radiating ribs, 4 to 6 per 1 mm. counted in the middle of anterior in adult, and combination of concentric faint lines of growth and irregularly spaced shingle-like undulations, usually spaced denser toward anterior. Minute hollow spines, tightly appressed to the summits of ribs and directed anteriorly are scattered over whole surface of shell.

Spines of ordinary chonetid kind seven to eight on each side of hinge in adult. Anterior and lateral areas of interior covered with radiating rows of pustules.

Ventral valve with prominent but very short medial septum just under the beak, bordered by a pair of longitudinal depressions with gently elevated imprints of suboval adductor muscle scars at the anterior. Anterior to these is a very low and narrow medial bar, on either side of which are broader but also very low elevations with a sub-regular single row of circular pustules along their summits.

Dorsal valve with short blunt cardinal process, roughly striated at apex; under it deep pit for insertion of the ventral septum. Anterior to it is a low medial bar, slightly more prominent than the opposing bar on ventral valve. There is considerable variability in outline of shell, so that in extreme cases the ratio of width to height reaches 2:1 and 1.5:1. The shells with these ratios may be provisionally recognized as varieties of *C. kingi*. The variety *A* with 2:1 transversely elongated shell is much flatter than typical *C. kingi*, and the variety *B* with 1.5:1 sub-square shell characterized by small size, its shell only up to 6.6 mm. wide and 4.4 mm. high.

Discussion.—The species is closely related to *Chonetes chesterensis*, which is the only species described by Weller (1915) from the Chester (Paint Creek) of Illinois, where it is rare. Easton (1943) lists three species of the genus *Chonetes* in the Pitkin (Chester) of Arkansas, but describes only one, *C. tumescens*. *Chonetes kingi* n. sp. differs from *C. chesterensis* by the more numerous spines along the hinge and by finer striae. Whether they differ internally is unknown, because in this respect the information on *C. chesterensis* is incomplete. From *C. oklahomensis* of the Pitkin of Oklahoma it differs in smaller size, smaller number of spines along the hinge line, and denser radiating costae.

Among the species of *Chonetes* known from the upper beds of the Morrow the nearest to *C. kingi* is *C. choteauensis* Mather, but the latter differs from the former by being proportionally larger transversely, and by a pronounced sinus. If Morningstar's identification of *C. choteauensis* from the lower Pottsville of Ohio is accepted, this species, or at least the form identified so by Morningstar, differs also by a smaller number of spines along the hinge line.

In table 2 are entered some of the principal dimensions for *C. kingi* and the related late Mississippian and early Pennsylvanian forms.

Many individuals of *C. kingi* are riddled by characteristic perforations of the boring sponge *Cliona paleodendrica* n. sp. It seems possible that selection by boring sponges of shells of particular genera and species has some stratigraphic significance, but the present record of the excavations in various paleozoic shells is obviously very incomplete, and stratigraphic value of certain combinations of boring sponges and their host shells remains an attractive subject for further research.

Genus PRODUCTELLA

Validity of the genus *Productella* has been recently disputed (Dunbar and Condra,

TABLE 2—PRINCIPAL DIMENSIONS IN MM. OF *Chonetes kingi* AND NEAREST SPECIES

Species and Authorities	Width	Height	Convexity	No. of spines	Ribs in Adult per 1 mm.	Sinus	Age
C. dominus King (1938)	14.7–20.3	10–14	3–4.6	11	4–6	distinct	Upper Marble Falls, Tex.
C. choteauensis (Morningstar, 1922)	10.2–12	6.2–8.5	2	4–5	?	shallow	Lower Mercer (Middle Pottsville) Ohio
C. choteauensis Mather (1918)	9.7	5.8	2	?	?	sharp	Upper Morrow, Ark.
C. kingi Elias, n. sp.	14–17	8–9.5	2.5–3	7–8	5–6	slight to none	Redoak Hollow, Okla.
C. kingi, var. *A*	14	7	1	?	6–7	none	
C. kingi, var. *B.*	4.4	6.6	1	5	5	none	
C. chesterensis Weller (1915)	12.5–12.6	8.2– 8.7	2–2.5	6	5–6	slight to none	Chester, Ill.
C. chesterensis Butts (1926)	16.5–17.5	10.5–12.5	?	?	?	none	Chester, Ala.
C. oklahomensis Snyder (1915)	11.5–13.5	17–19	3	3–12	?	?	Chester, Okla.

1932, p. 192) the genus believed to be "a 'dump box' for primitive productoids and including the ancestral radicles of several later genera." Such a drastically negative attitude implies, however, the position of *Productella* as an ancestral stock which existed in early Carboniferous time; hence its recognition has some stratigraphic value. Sutton (1938, p. 550) admits that the genus "has been rather loosely conceived in the past and made to embrace a large number of species." When reviewing American Mississippian species assigned to the genus he finds that only one of these, *Productella pyxidata* (Hall) "possesses both of the diagnostic characters of *Productella*, viz., the narrow cardinal areas and weakly developed articulating hinge teeth and sockets." Yet he lists in the genus five more valid Mississippian species, whose hinge apparatus is unknown.

PRODUCTELLA RECENSIS, n. sp.
Pl. 52, fig. 6

The single internal mold of a ventral valve of the described species from the Redoak Hollow is classified in *Productella* because even if its dental apparatus is not preserved, its small size, general shape, and sculpture are much like those in *Productella*, and particularly suggestive of this genus is its conspicuously wide, straight and narrow hinge surface, covered with fine longitudinal grooves. The conch was apparently very thin, as the outer sculpture is well reflected in the mold of the internal surface. It shows that the ventral valve was longitudinally plicated beginning at a distance of about 4 mm. from the apex. There are about 3 plications per 2 mm. at the posterior margin of the valve at 4 to 6 mm. distance from the apex. Very delicate, numerous concentric lines of growth traverse the conch, and become slightly more prominent at its maturity. There is no tendency for differentiation of auricles or development of spines, and the sides of the ventral valve run without any noticeable change into the straight hinge line, at which the valve becomes widest. Its principal dimensions are as follows:

Width	8 mm.
Height	5 mm.
Convexity	abt. 2–3 mm.

The species is the smallest among the known forms of the genus, and is also stratigraphically the highest.

Genus BUXTONIA
BUXTONIA SEMICIRCULARIS (Sutton and Wagner)
Pl. 56, fig. 14–16

1931. *Productus semicircularis.* SUTTON AND WAGNER, Jour. Pal., vol. 5, p. 23–24, pl. 5, fig. 20–22.
1938. *Buxtonia semicircularis.* SUTTON, Jour. Pal., vol. 12, p. 564, pl. 65, fig. 1.
1957. *Buxtonia semicircularis*, ELIAS, Jour. Pal., v. 31, p. 377, expl. to pl. 40.

Description.—Three dorsal valves represented by a combination of well preserved external and internal molds, and one internal mold of a ventral valve, so closely correspond in size, shape, and external sculpture to those of the type of *B. semicircularis* illustrated by Sutton and Wagner (1931, pl. 5, particularly fig. 21) that their identification with it seems fully justified. The most complete of the dorsal valves measures 27 mm. high and 39–40 mm. wide, and an incomplete ventral valve is slightly more than 30 mm. high and about 38 mm. wide (pl. 56, fig. 14), or slightly wider. These dimensions are close to the measured features on Sutton and Wagner's photographs (no measurements are given in their descriptive text). There are about 10 to 11 costae per 10 mm. on the mature or anterior parts of ventral and dorsal valves, same as mentioned by Sutton and Wagner in the descriptive text of *B. semicircularis.* There are also gentle concentric wrinkles over the visceral part of dorsal valves, and a few rows of spines over the produced or incurved part, the last features not mentioned in the previous descriptions of *B. semicircularis.* The form from the Redoak Hollow also has a few inconspicuous wrinkles developed over the posterior part of the ventral valve, which is triangular in outline; it has a small and pointed beak, which very slightly overhangs the cardinal edge.

Excellently preserved inner molds add the following previously unknown information on the interior and cardinal process of the species. Cardinal edge of ventral valve straight and narrow, longitudinally striated. Inner side of ventral valve covered by scattered and low, but sharply elevated radial ridges; a few of them in the medial part of the valve are quite long, but those on the flanks are uniformly short, and perhaps are actually adpressed spines, about 1.5 mm. long each. The medial elevation on the inside of the valve, which indicates the presence of medial sinus in its outer surface, seems shallower than as seen on the exterior of the ventral valve in the type of *B. semicircularis.* The interior surface of the dorsal valve displays a narrow median septum that extends over the whole length of the visceral part (pl. 56, fig. 15). On either side of it, slightly closer to the posterior than to the anterior, are sub-triangular muscular impressions, the angular sides of which point anteriorly. Between these impressions and the cardinal process are groups of faint stellar impressions, much like the same in *Dictyoclostus* sp. illustrated by Sutton and Summerson, 1943, pl. 54, fig. 2. Other details of sculpture are about the same as in this latter specimen. Cardinal edge of dorsal valve rises considerably outward near the cardinal process, thus producing a strong foundation about 12–14 mm. wide for it. The cardinal process itself is very short and trilobate.

The dorsal valves are infested by *Seminolithes clarkei* Elias (1957) and *Cliona paleodendrica* Elias (1957) see corresponding descriptions of these excavations.

Discussion.—The similarity of internal sculpture and of cardinal process in *Buxtonia* to those in genus *Dictyoclostus* can be observed equally well on the British representatives of the two genera, see illustrations by Davidson (1862, pl. XLII, fig. 5 and 6 for *Buxtonia scabriculus;* and by Muir-Wood, 1928, pl. VIII, fig. 3b,4 for *Dictyoclostus scotticus*). This emphasizes their close relationship, and it seems that their differentiation from each other is of sub-generic rather than generic rank. The evolutionary change from one to another is of some stratigraphic significance, because Buxtonia's first appearance is in the Mississippian, while *Dictyoclostus* seems to appear in early Pennsylvanian age.

BUXTONIA INCURVATUS (Sutton and Wagner)
Pl. 55, fig. 14–16

1931. *Productus incurvatus.* SUTTON AND WAGNER, Jour. Pal., vol. 5, p. 26–27, pl. 5, fig. 18,19.
1938. *Buxtonia incurvatus.* SUTTON, Jour. Pal., vol. 12, p. 564.

This species was established by Sutton and Wagner on ventral valves only, one of which was illustrated. Two ventral valves from the Redoak Hollow seem to be identical with this species. They are characterized by great gibbosity of the posterior or umbonal region which protrudes over the hinge line. The sculpture consists of typical buxtonian costae, which are, however, not very prominent. The medial sinus is barely perceptible, as described for the type of the species. Incompleteness of preservation prevents exact

measurements of the dimensions, but they are close to the measurements given by Sutton and Wagner (1931, p. 26), and perhaps are slightly larger: the hinge line in the larger of the two valves from the Redoak Hollow is about 45–46 mm., including distinct auricles, which, perhaps, were not fully preserved on the types of the species described by Sutton and Wagner.

BUXTONIA SUTTONI, n. sp.
Pl. 56, fig. 1–5

Description.—The species is based on dorsal valves only, three recovered nearly complete examples of which are represented by a combination of well preserved external and internal molds. They are flat to slightly concave, with straight hinge line 20 to 22 long, and a subreticulate sculpture of combined longitudinal costae and concentric undulations. The longitudinal costae are generally continuous throughout the valve, but their course is slightly tortuous, particularly in the umbonal area and on the flanks. Concentric sculpture consists of very fine lines of growth and more prominent undulations, but the latter never become sufficiently strong to interrupt completely the radial costae or cause them to stagger. Width and length of the adult dorsal valve varies from 18 to 24 and 16 to 20 mm. correspondingly. The well preserved inner molds of the dorsal valve shows the presence of a narrow central septum, that runs for about $\frac{2}{3}$ distance from the subdued beak. In the two examples it broadens in a wedge-like manner near the beak, and divides into two branches separated by a narrow central depression; the cardinal process, which the two branches run into, is trifid, the central branch in it being minutely transversely striated. In one of three examples of the valve, the central septum, instead of wedge-like expansion, widens suddenly and keeps its new width evenly for a distance of 2.5 mm. from the beak.

The spines are numerous, disposed along the summits of radial costae, inclined distad, and are arranged in checkerboard order in the neighboring costae. Only near the apex the spines become few and thin, but elsewhere they are numerous, and near the distal edge of adult stage and along the flanks the spines are arranged in concentric rows, as they mount the crests of concentric undulations.

Discussion.—The new species seems nearest to *Buxtonia arkansana* (Girty), judging by the illustrations and descriptions of the external appearance of its dorsal valve. The dorsal valve in *B. arkansana* is described as "for the most part nearly flat . . . about the margin, however, it is strongly and rather abruptly bent" (Girty, 1915, p. 46). Sutton and Wagner describe the dorsal valve of *Productus abruptus*, which Sutton subsequently identified with *B. arkansana* (1938, p. 564) in the same way: "it is only slightly concave in the posterior region but curves more abruptly in the anterior and lateral areas and is produced parallel to the pedicle valve" (Sutton and Wagner, 1931, p. 25). None of the three well preserved dorsal valves of *B. suttoni* n. sp. show any indication of downward drag or geniculation, that is their edges show no sharp marginal bend parallel to a would-be trail of pedicle (ventral) valve, but they are slightly convex, slightly greater at the beak, from which the maximum convexity spreads anteriorly in the form of a metrolite-shaped elevation.

Another distinction of *B. suttoni* from *B. arkansana* is in finer sculpture. The costae in the dorsal valve of the former are narrower, as they average from 2.5 to 4 per 2 mm., while in the latter, judging by the photographs of its dorsal valves illustrated by Girty (1915, pl. 2, fig. 5,7) and Sutton and Wagner (1931, pl. 5, fig. 16) they average 1.5 to 2.5 per 2 mm.

Genus DICTYOCLOSTUS
DICTYOCLOSTUS MESIALIS var. SPRINGERENSIS, n. var.
Pl. 56, fig. 6–10

1914. *Productus mesialis.* WELLER, *pars.*, Ill. Geol. Survey Mon. 1, p. 112–113; pl. 10, fig. 7–13 only (not pl. 83, fig. 14–17).

The few specimens of the strongly geniculate dorsal valves of the described form from the Redoak Hollow are much like the dorsal valve of *P. mesialis* from the chert at Pierce City, Missouri, the formation doubtfully correlated with the Keokuk by Weller (1914, explanation to plate 10). All illustrated specimens of the species from the locality in Missouri are smaller than the

TABLE 3—PRINCIPAL DIMENSIONS IN MM. OF *Dictyoclostus mesialis*

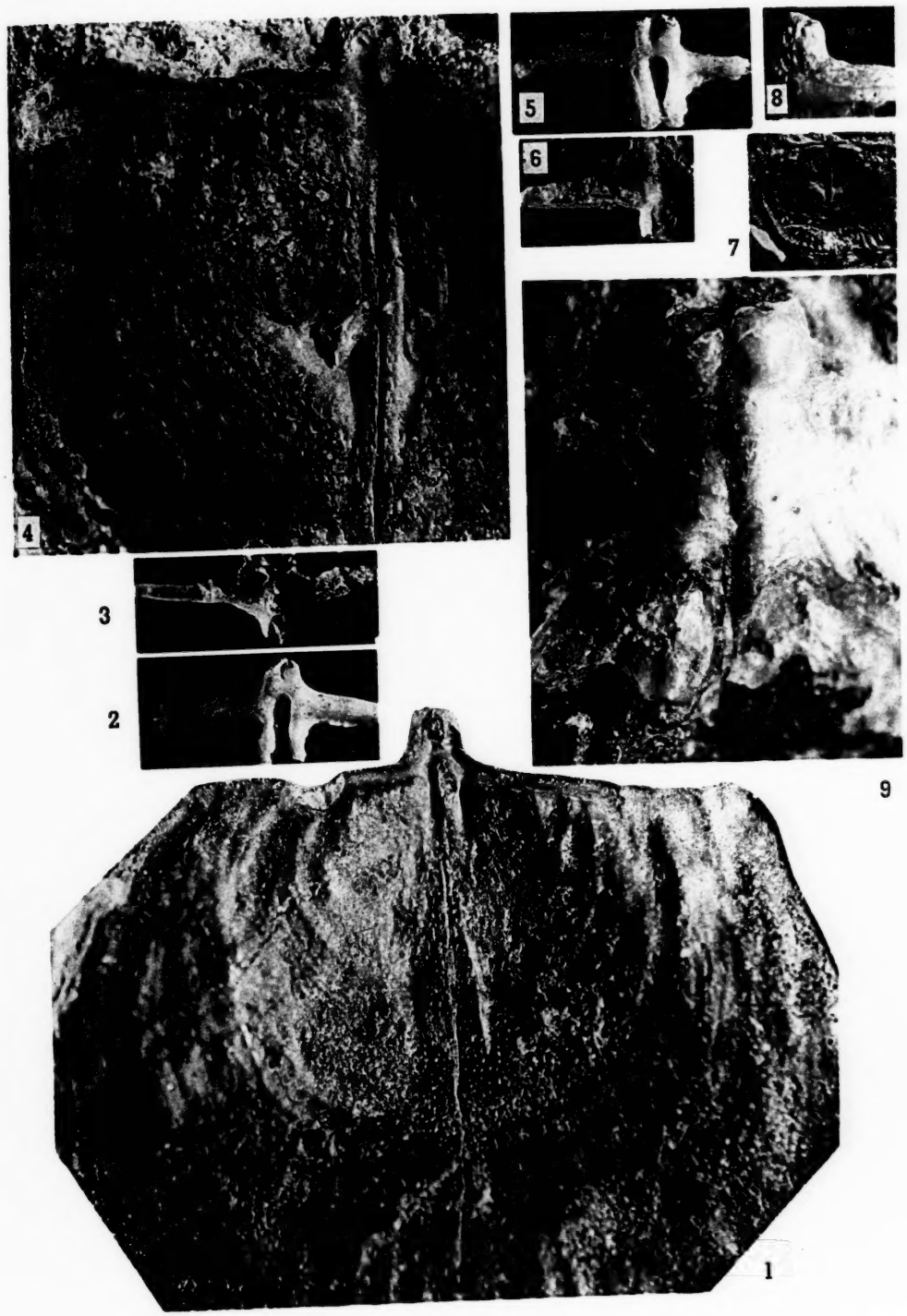
Specimens	Valve	Length from hinge line to anterior	Greatest width	Convexity	
D. mesialis	ventral	20.2	31	18	after Weller, 1914,
D. mesialis	dorsal	20.2	31	?	p. 113, measured
D. mesialis	ventral	21	31	12	on photographs
D. mesialis	dorsal	19	28	?	by Sutton, 1938
D. mesialis	ventral	15	20	11	measured on photo-
var. *welleri*	ventral	14	22	12	graphs by Wel-
n. var.	dorsal	15	22	?	ler, 1914
D. mesialis	dorsal	15	21.5	6	
var. *springerensis*	dorsal	16	20+	9	
n. var.	ventral		29−		

cotypes of Hall from the Keokuk of Illinois (Hall, 1858, p. 636–637, Pl. 19, fig. 2a–c), which are re-illustrated by Weller (1914, pl. 83, fig. 14–17). The second occurrence of shells of the same size in the Redoak Hollow indicates the desirability to differentiate the smaller shells at leasts as a variety of the typical form. The occurrence of such shells in the Redoak Hollow suggests that the chert at Pierce City may be of later Mississippian age than the Keokuk.

The larger of the two dorsal valves recovered from the Redoak Hollow is 15 mm. long and 21.5 mm. wide, which dimensions are very near those measured on Weller's pl. 10, fig. 13. *D. mesialis* var. *springerensis* differs from the latter by being widest at the middle of the valve, and not at the hinge line, which is the case in species *D. mesialis*. Another distinction of var. *springerensis* is much greater concavity of the whole visceral portion of the dorsal valve which is nearly flat in *D. mesialis*, with a "slight concavity towards the beak," as Weller describes and illustrates (1914, p. 113; Pl. 10, fig. 13, Pl. 83, fig. 17). In var. *springerensis* the concavity of the visceral part of the dorsal valve is greatest at the beak, and extends anteriorly in a metrolite-shaped manner, around the median part, which, therefore, appears elevated in between. Weller describes the similar elevation in *D. mesialis* as follows: "towards the front of the visceral surface the median portion of the valve is slightly elevated in an obscure median fold which becomes much stronger upon the anterior produced portion of the valve" (1914, p. 113). This is the same fold as in var. *springerensis*, and appears as a sharply defined sinus on its external mold, see the illustrations. The sculpture in both forms is also of the same nature and magnitude. The radiating costae in the dorsal valve of var. *springerensis* vary irregularly from .5 mm. to 1 mm. in width, but averaging 5–7 costate per 5 mm. along the median part of the "produced" or geniculate portion. The concentric "wrinkle-like markings," which cover the visceral portion of dorsal valve, are said to be "commonly rather faint"

EXPLANATION OF PLATE 53

FIG. *1–6—Diaphragmus fasciculatus* var. *bipilus*, n. var. ×10.
1—holotype: inner mold of dorsal valve; *2,3*,—cardinal area of the same detached from the mold, ventral (*2*) and dorsal (*3*) views; *4*,—paratype, inner mold of dorsal valve; *5,6*,—cardinal area of the same detached from the mold, ventral (*5*) and dorsal (*6*) views.
7–8—Diaphragmus fasciculatus var. *girtyi*, n. var. *7*,—holotype, inner mold of dorsal valve, ×2; *8*—cardinal area of the same detached from the mold, ventral view, ×10.
9—Productus stehlii, n. sp. Holotype, cardinal process and adjacent part of dorsal valve, viewed dorsally, ×10.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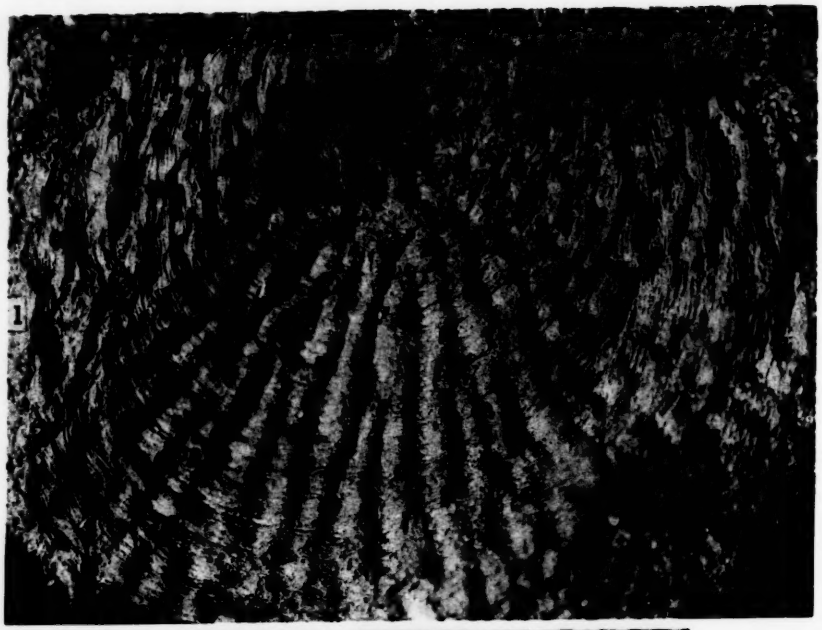
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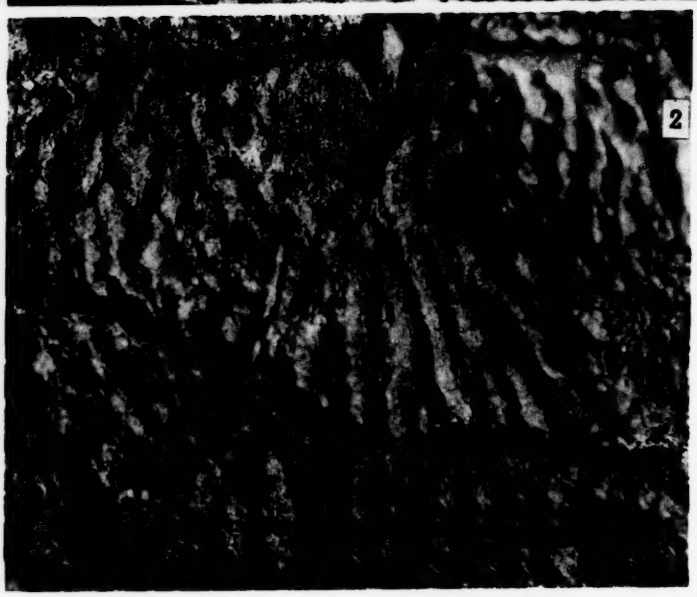
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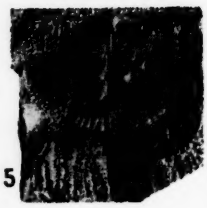
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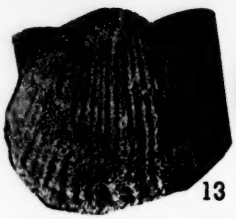
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(Weller, 1914, p. 113) in *D. mesialis* and are more prominent in var. *springerensis*, but their spacing is about the same in both forms.

The cardinal process has not been described or illustrated for *D. mesialis*. In var. *springerensis* it is 1 mm. long and distinctly trilobate, as typical for genus *Dictyoclostus* (see Sutton and Summerson, 1943, Pl. 54, fig. 2–8).

The specimens of *D. mesialis* from the the chert of Pierce City, Mo., can be designated as var, *welleri*, their difference from the typical form from the Keokuk of Illinois being smaller size. Table 3 illustrates this difference.

DICTYOCLOSTUS sp. cf. D. INGRATA (Girty)
Pl. 55, fig. 1–4

1903. *Marginifera ingrata*. GIRTY, U. S. Geol. Survey Prof. Pap. No. 16, p. 379–380, pl. V, fig. 12,12a,13,13a,13b.

Description.—The material from the Redoak Hollow, which is classified provisionally with *D. ingrata* Girty from the Pennsylvanian of Colorado, is characterized by an extensive development of transverse wrinkles, which cover the posterior two thirds or more of the ventral valve, and are almost as densely spaced as the radiating costae.

The dimensions of the most complete specimen (pl. 55, fig. 1,2) are 13 mm. long, 15 mm. wide, and covexity 5.5 mm.; and the largest, though incomplete ventral valve is 15 mm. long. These dimensions are not far from those for the single valve measured by Girty: 11 mm. long and 15 mm. wide (1903, p. 379), and the concavity is 5.5 mm., as can be measured on Girty's pl. V, fig. 12a and 13b. There are from 7 to 9 costae per 5 mm. at the middle part of the anterior, which also compares satisfactorily with 7 per 5 mm. in *M. ingrata* Girty. The form is subquadrate in outline, with well defined large ears, which are crossed by strong wrinkles, and tend to develop a few coarse spines along the hinge. The beak is only slightly protruding over the hinge, and on some individuals there is a very faint indication of a sinus, a feature absent in Girty's types.

Discussion.—The species is smallest of the genus, and close to the form described by Girty as *Marginifera ingrata*. This latter species was differentiated from all other species of *Marginifera* by its "strong wrinkles and striae conjoined with the absence of a sinus" (Girty, 1903, p. 379), and the form from the Redoak Hollow has these features, but the strong and regularly disposed wrinkles in it seem to extend over a larger ventral part than as shown on Girty's illustrations.

(?) New Genus, aff. MARGINIFERA
Pl. 54, fig. 3,4

Description.—The peculiar character which distinguishes the apical part of a very small single ventral valve of this form is the presence of a group of paired spines upon the central part of its protegulum, which is .8 mm. long and 1 mm. wide. The shell is so unusually thin that its inner mold (pl. 54, fig. 4) even at the very beak reflects prominently nearly all the fine details of the exterior, including the paired apical spines and the coarser lines of growth. The external sculpture consists of radial ribs, whose number enlarges by intercalation,

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EXPLANATION OF PLATE 54

FIG. *1,2—Avonia* (?) *spinosa*, n. sp. Holotype, outer (*1*) and inner (*2*) molds, ×10.
3–4—New genus (?), cf. *Marginifera*. Inner mold (*3*) of ventral valve viewed ventrally, and outer mold (*4*) of the same valve viewed anteriorly, ×10.
5—Diaphragmus fasciculatus (McChesney). Inner mold of dorsal valve, ×2.
6–9—Diaphragmus fasciculatus var. *bipilus* (?) n. var. Outer molds of young dorsal valves, ×2; ventral views (*6,8*) and lateral views (*7,9*) of two individuals.
10–14—Productus parus var. *matheri*, n. var., ×2. *10–12*, holotype, inner mold of ventral valve viewed ventrally (*10*) and laterally (*11*); incomplete outer mold of same valve viewed dorsally (*12*). *13,14*, paratype, inner mold of ventral valve viewed ventrally and laterally.

and of uniformly spaced growth lines. One pair of the apical spines is more prominent than the two pairs of the small spines posterior to it and spaced closer to each other. The small area that is surrounded by these apical spines is somewhat depressed. No other spines can be seen anywhere on the fragmental valve.

Discussion.—In a search for similar spines in the apical part of the ventral valve, they have been found only in some examples of *Marginifera* from the mid-continent (*M. muricata*, *M. wabashensis*, *M. fragilis*), but in all these species the ventral valves are invariably thicker, and besides large spines abound over all of their surface —which is not the case in the peculiar valve here described. The single specimen represented by the illustrated external and internal molds is too incomplete for erection of a new genus and species, and so it is here recorded without taxonomic name, and only tentatively compared with *Marginifera*.

Genus PRODUCTUS

PRODUCTUS PARVUS, *sensu lato.*

1860. *Productus parvus*, MEEK AND WORTHEN, Proc. Acad. Nat. Sci., Philadelphia, p. 450.
1866. *Productus parvus*, MEEK AND WORTHEN, Ill. Geol. Surv., vol. 2, Pal., p. 297–298, pl. 23, fig. 4a-e.
1888. *Productus parvus*, HERRICK, Denison Univ. Sci. Lab. Bull., vol. 4, pl. 11, fig. 11.
1914. *Productus parvus*, WELLER, Ill. Geol. Survey., Mon. 1, p. 121–122, pl. XVI, fig. 16–22.
1928. *Productus redesdalensis*, MUIR-WOOD, Mem. Geol. Survey Great Britain, Pal., vol. III, pt. 1, p. 61–64, pl. II, fig. 9–11, text-fig. 14.
1938. *Dictyoclostus parvus*, SUTTON, Jour. Pal., vol. 12, p. 563.

The shells of this comprehensive species are small, with subequal length and width, and considerable convexity. In spite of the fairly common occurrence of the species its internal characters are still unknown, and its dorsal valve has been illustrated but once (Weller, 1914, pl. XVI, fig. 17). It is said to be "deeply and rather regularly concave, . . . nearly in contact with the opposite valve, the auricular portions at the cardinal extremities somewhat differentiated from the general surface. Surface marked by radiating costae similar to those of the opposite valve and also by concentric markings; spines bases apparently infrequent or absent" (Weller, 1914, p. 122).

Productus redesdalensis Muir-Wood, here included in this broad species, is said to be "as a rule, ornamented with costae as on the visceral disk. The ornament of this valve is similar to that of the pedicle valve" (Muir-Wood, 1928, p. 62). Weller measures in *P. parvus* "the depth of visceral cavity between the two valves 5.2 mm.," and in Muir-Wood's natural size text-figure the depth of the restored visceral cavity is shown about 6 mm. For further discussion of this British form with *P. parvus* see the following description of *P. parvus* var. *matheri*.

PRODUCTUS PARVUS var. MATHERI, n. var.
Pl. 54, fig. 10–14; Pl. 55, fig. 5,6,17–19

Description.—New variety is practically of the same shape and dimensions as *P. parvus*. Measurements of its two complete adult valves, made on the internal molds, are as follows: length 13 to 14 mm.; width 14 and 16 mm., and convexity 8 and 7 mm. It has no trace of a sinus and the few irregularly spaced concentric wrinkles on its posterior part are inconspicuous, though they become more prominent on the auricles, which are well differentiated. The distinction from *P. parvus* consists only in wider longitudinal costae: they are fairly uniform in width, and in the middle part of the anterior margin 2.5 to 3 costae occupy the space of 2 mm. while in *P. parvus* 4 costae occupy the same space.

Discussion.—The distribution of spines in the valves from the Redoak Hollow is like that in *Productus parvus*, and nearest to that of the example from the "Pella beds, Pella, Iowa" illustrated by Weller (1914, pl. XVI, figs. 20–22). In this example the spines are concentrated upon the ears and the adjacent part of the slope of the valve. This arrangement overshadows the regularly arranged row, usually or always present upon each side of the beak, starting close to the hinge line and describing a curve around the base of the auriculation to the lateral margin, etc., as Weller describes (1914, p. 122). The example from the Pella beds deserves to be differentiated as variety *pellaensis* of *Productus parvus*, just as the Redoak Hollow examples are here designated *P. parvus* var. *matheri;* they stand closer to the variety from the Pella beds than to the typical examples of *P. parvus* from the Chester.

The generic classification of this small productid is somewhat arbitrary for the following reasons. Only its ventral valves are known, whose characters are intermediate between the Mississippian *Productus parvus* Meek and Worthen (1866, p. 297, pl, 23, fig. 4a–3), on one hand, and the lower Pennsylvanian *Productus nanus* Meek and Worthen and *Marginifera missouriensis* Girty, on the other. While it is probable that *P. nanus* should be classified with *M. missouriensis* both generically and specifically (Dunbar and Condra, 1932, p. 224–225), the comparison is uncertain because neither character of dorsal valve, nor interior of *P. nanus* are known; and the reference of both to *Marginifera* may be seriously questioned. Thus Sutton (1938, p. 563) places *P. parvus* in *Dictyoclostus* and not in *Marginifera*, where he places only one Mississippian species: *Marginifera adairensis* Drake. Placement of *P. parvus* in *Dictyoclostus* is also arbitrary, as the concentric wrinkles in the posterior of its ventral valve are "rather inconspicuous" (Weller, 1914, p. 122), and therefore the valve lacks the "semireticulate" surface characteristic of genus *Dictyoclostus*.

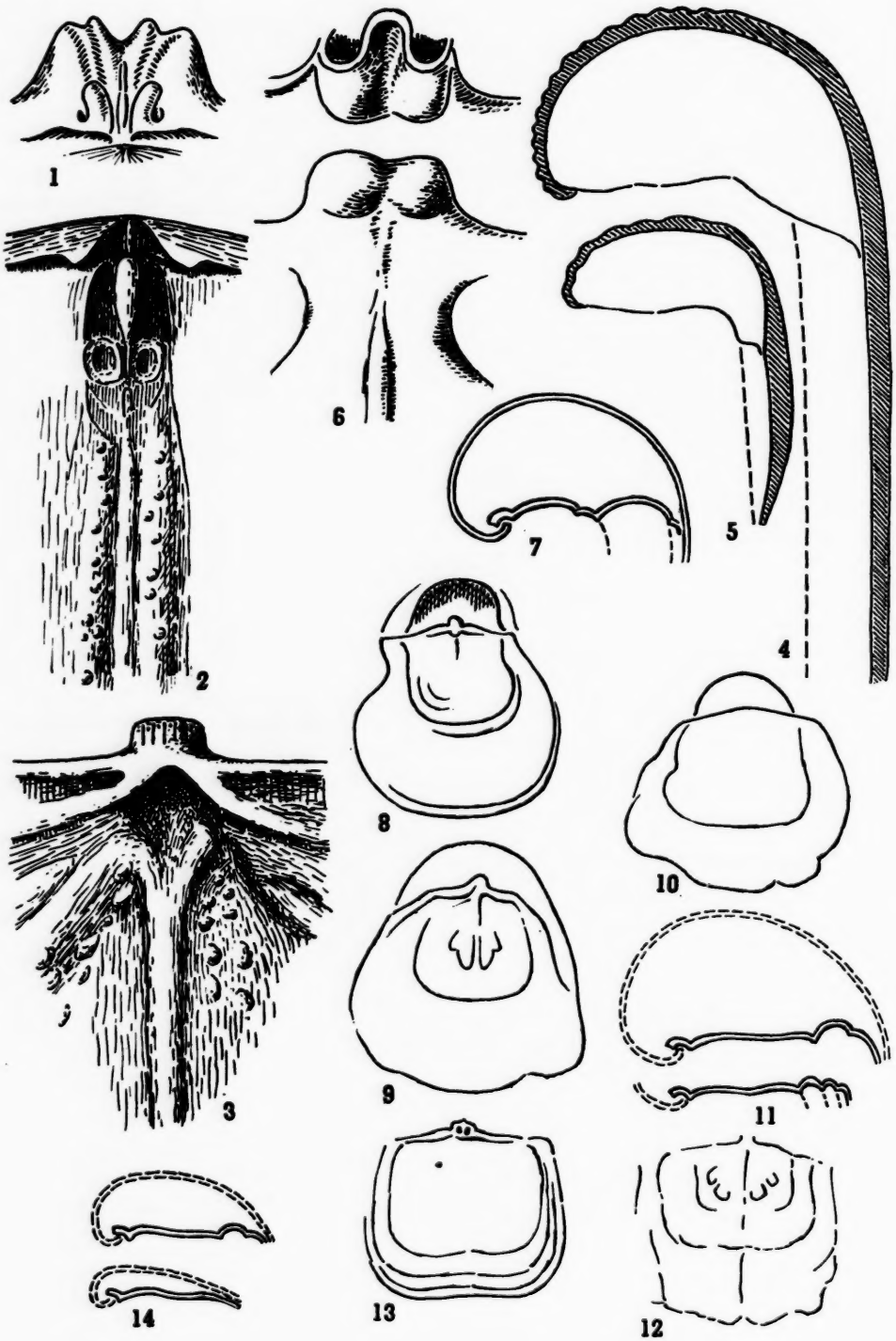
The successor of *P. parvus* var. *matheri* in the Morrow is *P. nanus*, which was described by Mather (1915, p. 156) and has the following dimensions measured on two complete ventral valves: length 10.4 and 10.7 mm.; width (along hinge line) 12.5 and 11.2 mm., and convexity 6 and 7 mm.; this is a distinctly smaller form than *P. parvus* and its variety *matheri*. On the other hand its longitudinal costae are much like the same in var. *matheri*, "7 or 8 costae occur in 5 mm. in the central portion of the venter," that is about 3 per 2 mm. In other respects the form is much like var. *matheri*.

As noted above, *Productus redesdalensis* Muir-Wood (1928, p. 61–64, pl. II, fig. 9–11, text fig. 14) from D_1 and D_2 zones of the Avonian of British Isles bears considerable resemblance to *D. parvus* var. *matheri*, and particularly striking is the similar crowding of spines upon the ears in the British form (ibid., pl. II, fig. 11). However, the British species is larger, longer than wide, and is proportionally thicker (more convex), its dimensions being: 25 mm. high, 22 mm. wide, and 16 mm. thick (ibid., p. 61). If this species is retained in genus *Productus* in restricted sense, where Muir-Wood places it, then to the same genus should be referred *Productus parvus* and its varieties. Specimen illustrated on Pl. 17, fig. 11–13 is considered a juvenile ventral valve of *P. stehlii* rather than an adult of *P. parvus* var. *matheri* because of its finer longitudinal costae and medial sinus.

PRODUCTUS STEHLII, n. sp.
Pl. 53, fig. 9; Pl. 55, fig. 7–13; text-fig. 6

Classification of this new species with genus *Productus* in restricted sense (Muir-Wood, 1928, p. 32–35; Dunbar and Condra, 1932, p. 177, 187, 191; Sutton, 1938, p. 558–559) is based on the combined evidence of the external sculpture of a partially crushed ventral valve of the holotype, and of the internal characters of an isolated dorsal valve. In addition many specimens of juvenile ventral valves, and one internal mold of a juvenile dorsal valve have been recovered.

The holotype is a ventral valve (not a mold) crushed in a direction almost perpendicular to its mature (anterior) part, hence its true thickness is reduced to about half, and the flattened shell spreads to about 125% of its true width. Otherwise the valve is in a nearly perfect state of preservation, as it is built by the original lustrous laminated calcite, with external sculpture fully intact. Unfortunately both ends of the hinge line broke when the tough ferruginous rock in which it is embedded was cracked open; the preserved part of the hinge measures 18.5 mm. long, while its restored length is apparently circa 25 mm. The maximal width of the flattened shell is 30 mm., but taking into account the increase of width due to the mechanical flattening, its true width must have been also circa 25 mm. or less. The partial flattening did not level out the well developed medial sinus in the anterior $\frac{2}{3}$ of the valve. Here, the sculpture consists of parallel rounded costae, which very gradually increase in width towards the anterior, with practically no additional costae developed. There are very few and scattered bases of spines, which rise upon the summits of some costate. The whole of the anterior is very much the same as illustrated and described for *Productus insculptus* Muir-Wood (1928, p. 89–92, pl.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III, fig. 10–12) which occurs in sub zone D_2 of the Visean of British Lower Carboniferous. The similarity of the sculpture includes equal number of costae per given space at a distance of 15 mm. from the beak: 15 per 10 mm. as counted by Muir-Wood (1928, p. 90), and as counted now on the described valve from the Redoak Hollow. The costae within its trail gradually bifurcate (see right lower side of pl. 53, fig. 15); Muir-Wood states that in *P. insculptus* they are "rarely bifurcating," and "bifurcating of the costae may occur on the trail."

The posterior of the ventral valve has not been affected by crushing, and its shape and fine sculptural details are intact (pl. 53, fig. 13). Its sculpture is made of radiating costae and concentric wrinkles, the latter densely spaced near the beak, but becoming scarcer after the distance from it reaches 6 mm. The ears are well developed and sharply differentiated from the inflated umbo by the deep linear depressions each at about 40° to the hinge line; this feature is much the same as in *Productus insculptus* (Muir-Wood, 1928, pl. III, fig. 11c). At least two differences exist between this species and *P. stehlii*, which justify specific distinction. The medial sinus in *P. insculptus* starts very near its beak, while in the species from the Redoak Hollow it starts only at about 10 mm. or more from the back. In *P. insculptus* there is a single row of prominent spines, "set in front of or on the ridge of the flanks" (Muir-Wood, 1928, p. 90; pl. III, fig. 10b, 11a), while none are developed along the hinge line. In *P. stehlii*, on the contrary, prominent spines are developed subparallel to the hinge line, increasing in strength toward its ends, at least four, and probably five (including the inferred spine on its broken off ends) of them in a gently curving row; but none on the flanks, where there are many in *P. insculptus*.

The single inner mold of a dorsal valve is assigned to *Productus stehlii* because it is very similar to the inner molds of dorsal valves of the closely related *Productus concinnus* Sowerby and of *P. vaughani* Muir-Wood, both from the Lower Carboniferous of British Isles; and in its size it would fit well inside the above described ventral valve. This conclusion is verified by the identity of its cardinal process with that in the holotype, as it was uncovered in the latter by breaking off its apical part subsequent to photographing.

Most striking about the described inner mold of the dorsal valve is that besides the well developed cardinal area, cardinal process, muscle scars, and brachial impressions, it shows the reticulate sculpture of the shell, as clearly as if it were its external mold. The very similar combination of the internal and "external" characters can be observed on the fine photograph of the "interior of brachial valve" of *Productus concinnus* (Muir-Wood, 1928, pl. 1, fig. 9). There are at least two, but seemingly only minor differences between the interior of the dorsal valve of *P. concinnus* and *P. stehlii*. One is greater convexity of the latter, and a resultant sharper differentiation of the ears. In this respect the dorsal valve of *P. stehlii*

TEXT-FIG. *1–14*

1—N. gen. (?), aff. *Derbyoides* Dunbar and Condra. Cardinal process, ×15.
2,3—*Chonetes kingi*, n. sp. Interior of central part of cardinal area in ventral and dorsal valve, ×10.
4—*Productus productus* (Martin), Lower Carboniferous, England. Schematic cross-section of shell, after Muir-Wood, 1928, text-fig. 11.
5—*Productus concinnus* Sowerby, Lower Carboniferous, England. Schematic cross-section of shell, after Muir-Wood, 1928, text-fig. 12.
6—*Productus stehlii*, n. sp. Ventral and top views of cardinal process, ×10.
7–9—*Diaphragmus elegans* Girty. *7,8*, cross section and dorsal view of shell, Paradise formation, Arizona, ×2 (var. *A*); *9*, Sketch of dorsal view, adapted from Butts, 1926, pl. 60, fig. 7, Chester series, Alabama, ×2.
10–13—*Diaphragmus fasciculatus* (McChesney), Upper Mississippian, Arkansas. *10*, Sketch of dorsal view, adapted from Muir-Wood, 1928, pl. III, fig. 2, ×1; *11*, Cross-sections of two dorsal valves and of restored valve, ×2; *12*, External mold of dorsal valve, ×2; *13*, Internal view of dorsal valve, ×2. *11* to *13* from the Redoak Hollow.
14—*Diaphragmus fasciculatus* var. *girtyi*, n. var. Cross-sections of two dorsal valves, ×1.

is more like the dorsal valve of *P. insculptus*. The other difference is the development of a sharp linear division in each of the paired muscle scars of *P. stehlii*, a feature not as clearly or sharply developed in *P. concinnus* (Muir-Wood, 1928, pl. 1, fig. 2). The rest of the details are much the same in both American and British species.

It may be concluded that *P. stehlii* is a species closely related to *P. insculptus* and *P. concinnus* from zone D_2–D_3 of the Lower Carboniferous (Avonian) of British Isles, that is the lower part of the upper Visean of the standard Dinantian of the Old World.

Genus DIAPHRAGMUS Girty

1911. Subgenus *Diaphragmus*. GIRTY, U. S. Geol. Survey Bull. 439, p. 51–53. pl. IV, fig. 4,5.
1914. *Diaphragmus*. WELLER, Ill. Geol. Survey, Mon. 1, p. 135–138, pl. XII, fig. 8–17.
1915. *Diaphragmus*. GIRTY, U. S. Geol. Survey Bull. 493, p. 50–59, pl. III, fig. 1–5.
1928. *Diaphragmus* (not considered valid genus). MUIR-WOOD, Mem. Geol. Survey Great Brit., vol. III, pt. 1, p. 21–23, pl. II, fig. 1,2.
1932. *Diaphragmus* (not considered valid genus). DUNBAR AND CONDRA, Nebr. Geol. Survey 2nd Ser., Bull. 5, p. 188, 214.
1932. pars. *Productus*. SUTTON, Jour. Pal., vol. 12, p. 559, pl. 64, fig. 9–12.

Much discussion has been devoted to the characteristics of the genus and its relationship to *Productus* and *Marginifera*. Attention was concentrated on the structure and nature of the so-called *diaphragm*, a flange-like platform that surrounds (except at the hinge) the visceral disk of the dorsal valve, sealing off anteriorly the visceral cavity, and marking the boundary of the ventral and dorsal trails. Girty correctly understood the taxonomic implication of the diaphragm, as he differentiated the productids which possessed it into his subgenus *Diaphragmus*, which he found restricted to the upper Mississippian of America. However, Muir-Wood discovered the existence of a similar type of diaphragm in the group of British productids which belong to genus *Productus* in restricted sense, as per her emendation of its scope. An excellent specimen of "*Diaphragmus elegans*" placed at her disposal (Muir-Wood, 1928, pl. II, fig. 1,2) enabled her to make accurate comparison, and her comparative analysis of this American and related British species has been accepted by the subsequent American writers as indicative of generic identity of *Diaphragmus* and *Productus* (Dunbar and Condra, 1932, p. 214; Sutton, 1938, p. 559). In spite of the repeated descriptions and discussions no data have been published on the internal structure of *Diaphragmus* other than those about the diaphragm, and these are now being supplemented by the present observations on the material from the Redoak Hollow, see the following descriptions. It seems to furnish some evidence in favor of differentiation of *Diaphragmus* from *Productus*. Further evidence is furnished by the difference in the level of the diaphragm in relation to the visceral disk. In *Productus* ss. (em. Muir-Wood) the diaphragm is shown by Muir-Wood as bending down from the edge of the visceral disk (diagrammatic longitudinal section, text-fig. 11, p. 40; text fig. 12, p. 49; and others; also Dunbar & Condra, 1932, text fig. 9, p. 178; and Sutton, 1938, text fig. 1d). But in *Diaphragmus*, as observed on the abundant dorsal valves and their molds from the Redoak Hollow, and as seen in Girty, 1915, pl. III, fig. 4, the diaphragm bulges upwards above the level of the visceral disk. The difference is shown here on the diagrammatic longitudinal sections for *Productus productus*, and for *Diaphragmus elegans* and *D. fasciculatus*, text-fig. 4,5,7. Still further difference is in the more complex form of diaphragm in *Diaphragmus*, which is manifest by the occurrence of two to three successive concentric diaphragms. This was observed by Girty, as cited from his letter to Muir-Wood (Muir-Wood, 1928, p. 22): "the diaphragm is . . . given off at the point of geniculation of the branchial valve, and extends in the plane of the visceral disk, but on meeting the trail of the pedicle valve it is deflected anteriorly along the inner surface of that valve, thus repeating the trail of the brachial valve. *This repetition of the trail may occur two or three times in one specimen. . .* " (my italics). This repetition is evident on the most complete dorsal valves of *Diaphragmus* from the Redoak Hollow (pl. 55, fig. 23).

In view of the observed differences *Diaphragmus* may be considered a genus at a par with *Productus*, though nearer to it than any other productid genera now recognized. Or it may be considered a sub-

genus of *Productus*, as originally suggested by Girty, a degree of taxonomic differentiation which may be shared with it by a few other productid "genera."

Stratigraphic range of *Diaphragmus* about equals that of *Productus* s.s., as it occurs throughout the upper Mississippian, from Moorefield shale upwards; the present discovery of it in the Redoak Hollow carring it to about the same level at which small *Diaphragmus*-like productids, such as *P. coscinnus* and *P. carbonarius* occur in the British Isles, that is, up into the basal Millstone Grit.

Generotype: *Productus fasciculatus* McChesney, as per the decision reached in the subsequent discussion under *D. elegans*.

Diagnosis.—The following characters are suggested for the differentiation of *Diaphragmus* as a genus distinct from *Productus* ss. (1) larger size of diaphragm, which in most typical examples is differentiated into three concentric parts; and (2) smaller size of trail, which is shorter than the width of the diaphragm. In *Productus* s.s., on the contrary, the trail is many times longer than the width of the diaphragm.

DIAPHRAGMUS ELEGANS (Norwood and Pratten)
Text-fig. 7–9

1854. *Productus elegans*. NORWOOD AND PRATTEN, Acad. Nat. Sci. Philadelphia, Jour., 2nd Ser., vol. 3, p. 13; pl. 1, fig. 7a-c.
1877. *Productus elegans*. HALL AND WHITFIELD, U. S. Geol. Expl. 40th Par., Rept., vol. 4, p. 268, pl. 5, fig. 3,4.
1891. *Productus elegans*. WHITFIELD, N. Y. Acad. Sci., Ann., vol. 5, p. 581, pl. 13, fig. 15,16.
1897. *Productus cestriensis*. WELLER, N. Y. Acad. Sci., Trans., vol. 16, p. 256, pl. 19, fig. 7–9.
1911. *Productus cestriensis*. MORSE, Proc. Ohio State Acad. Sci., vol. 5, p. 372, fig. 9a-g.
pars 1914. *Diaphragmus elegans*. WELLER, Ill. Geol. Survey, Mon. 1, pp. 136–138, pl. XII, fig. 13–15 (only).
1926. *Diaphragmus elegans*. BUTTS, Ala. Geol. Survey, Spec. Rep. No. 14, pl. 65, fig. 6,7.
1935. *Productus elegans*. HERNON, Jour. Pal., vol. 9, p. 681, pl. 81, fig. 2a,b.

The above listed synonymy for *Diaphragmus elegans* prior to 1911 is the same as published by Girty in 1915, p. 59, except the omission of the papers not accompanied by illustrations. The synonymy starting from 1911 and to date is added after comparative study and measurements of the published illustrations.

In the present understanding of *D. elegans* it differs from *D. fasciculatus* in having the visceral disk about as wide as long, to only slightly wider than long; while the visceral disk in *D. fasciculatus* is about $1\frac{1}{3}$ as wide as it is long, and is more trapezoidal than subquadrate. *D. fasciculatus* also differs from *D. elegans* by the development of a medial sinus and by the occasional fasciculation of the costae, but these characters are not always clearly developed to allow unmistakable identification, and thus they serve only as supplementary characteristics. Unfortunately, in spite of his prolonged study and repeated publications of various examples of genus *Diaphragmus*, Girty did not describe or illustrate a single example of undoubted *D. elegans*, which supposedly serves as genotype of his subgenus *Diaphragmus* because it is the only species which he originally (Girty, 1911) included in it. Girty's own single earlier example, which he identified in 1911 with *D. elegans*, has been subsequently reinstated by him as *D. fasciculatus* (McChesney) (Girty, 1915, p. 56, synonymy). Thus it appears clear that Girty actually established the internal characters on which he proposed to differentiate subgenus *Diaphragmus* not on *Productus elegans* (Norwood and Pratten) but on *P. fasciculatus* (McChesney). There seems no doubt that he composed his earlier synonymy of *P.* (*Dictyoclostus*) *elegans* by comparison of only external features of published material, and only assumed that the specimens in the publications of the composed synonymy have the same internal character, viz. diaphragm, the presence of which he established on the material which he evidently concluded to be *D. fasciculatus*. Trusting that his latter identification is correct, and I believe that it is so—the inevitable inference is that he erected his genus actually not on *D. elegans*, as he thought, but on an example of *D. fasciculatus*. Thus, the fact that he erroneously identified, as he admits, this example with *Productus elegans* does not make *P. elegans* the genotype of *Diaphragmus*. Further evidence to the correctness of this understanding is provided in the illustration by Muir-Wood of the example of genus *Diaphragmus* sent to

her by Girty (Muir-Wood, 1928, p. 20–23, pl. II, fig. 1,2), and on which the main diagnostic character of the genus was, for the first time, analytically compared (by her) on actual material with the corresponding character in genus *Productus*, in the sense of the latter as emended by Muir-Wood. The observations and measurements of the visceral disk in *D. elegans* on her illustration now lead to the conclusion that this is an example of *D. fasciculatus*. Furthermore, it is apparently on this example that Girty explained in detail the *complex diaphragm* of *Diaphragmus* in a letter to Muir-Wood, as quoted by her (1928, p. 22); and it is partly on the evidence of the complexity of the diaphragm in *Diaphragmus*, as compared with the less complex diaphragm in *Productus* s.s., that the genus *Diaphragmus* is here reinstated.

To recapitulate the evidence:

(1) Girty introduced the subgenus *Diaphragmus* in 1911 on the presence of a diaphragm, the diagnostic character of the subgenus, as it was observed by him in *Productus fasciculatus*, though misidentified by him (at this time!) with *Productus elegans*.

(2) Example of *Productus fasciculatus* was subsequently sent by Girty to Muir-Wood, though misidentified as *P. elegans*, and thus illustrated by her under this name.

(3) Girty explained in a letter to Muir-Wood, as quoted by her, the complexity of the diaphragm in *Productus fasciculatus* (mistakenly identified as *P. elegans*). Consequently, *Productus fasciculatus*, and not *P. elegans* must be considered the genotype of *Diaphragmus*.

(4) The complexity of the diaphragm in *Productus fasciculatus* is here considered diagnostic for differentiation of *Diaphragmus* Girty from *Productus* ss., em. Muir-Wood.

None of the material described or illustrated by Girty (1911, 1915, 1927) belongs to typical *Diaphragmus elegans*. The example from the Moorefield shale of Arkansas described in 1911 is subsequently reidentified as *D. fasciculatus*. The examples from the Batesville sandstone of Arkansas illustrated and discussed under the heading of *Diaphragmus elegans* (Girty, 1915, p. 59) is adjudged by Girty himself as "a mutation which it may be perhaps desirable to distinguish from typical *D. elegans* in some subordinate category,"—and no typical material for *D. elegans* is illustrated or mentioned. Finally, the examples from the Brazer limestone of Idaho formally identified with *D. elegans* (Girty, 1927, pl. 23, fig. 20–27) to me do not seem typical for *D. elegans*, and the measurements of visceral disk are different from those established for *D. elegans*. Though Girty (1927, p. 71) states that he used *D. elegans* among a few other invertebrates "for identifying the Chester horizon of the Brazer," he does not

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EXPLANATION OF PLATE 55

FIG. *1–4*—*Dictyoclostus* cf. *ingrata* Girty. Internal molds of ventral valve, ×2. *1,2*, ventral and lateral views; *3,4*, posterior and ventral views of another specimen.

5,6—*Productus parvus*, var. *matheri*, n. var. Inner mold of ventral valve viewed ventrally (*5*) and laterally (*6*), ×2.

7–13—*Productus stehlii*, n. sp. *7–9*, posterior, ventral, and lateral views of the holotype, ×1; *10*, clay squeeze from inner mold of a dorsal valve, ×2. *11–13*, ventral valve of juvenile individual: posterior and ventral views of its internal mold (*11,12*) and its outer mold (*13*), ×2.

14–16—*Buxtonia incurvatus* (Sutton and Wagner). Lateral view (*14*), posterior view (*15*), and ventral view (*16*) of internal mold, ×1.

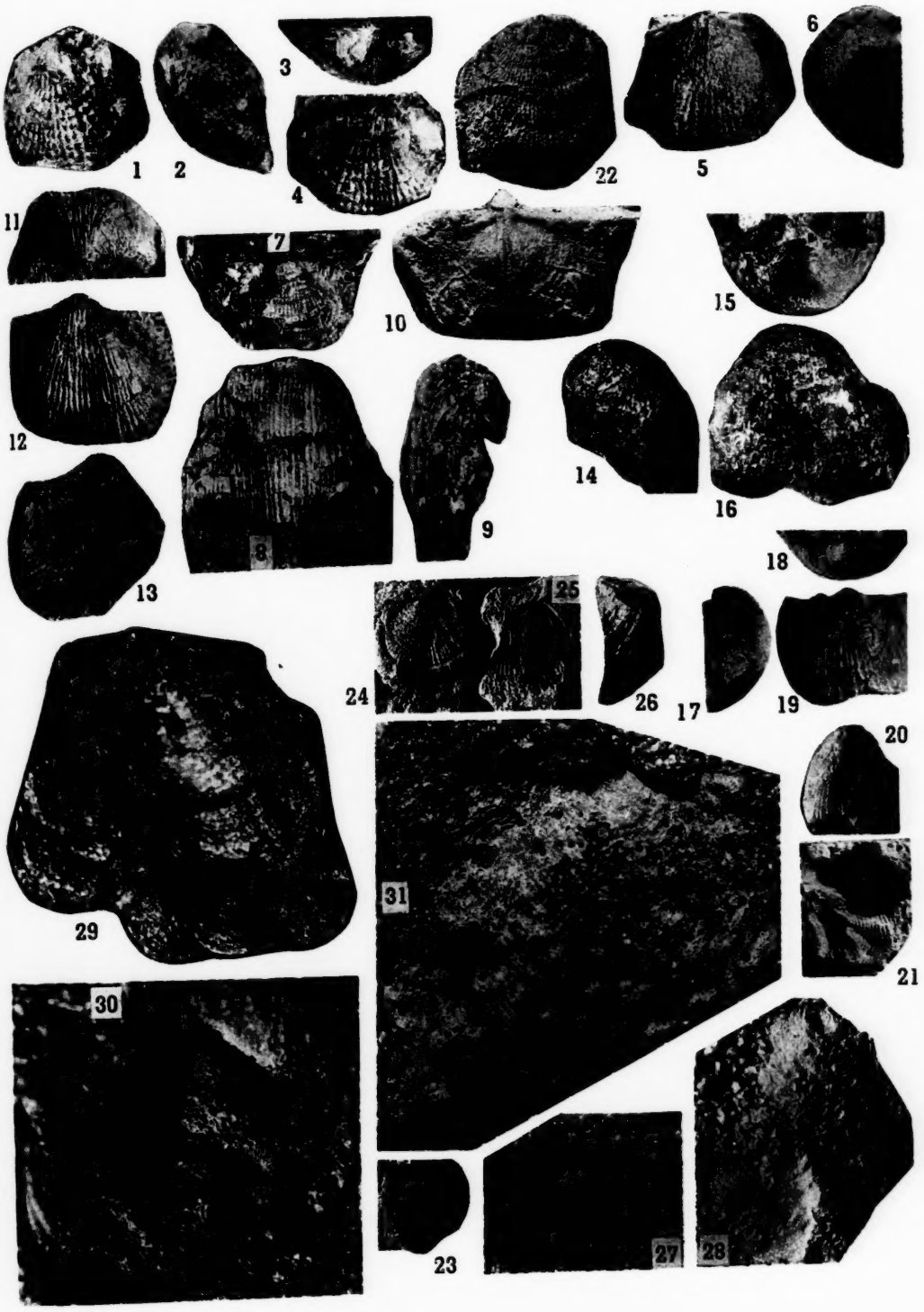
17–19—*Productus parvus* var. *matheri*, n. var. Lateral view (*17*), posterior view (*18*), and ventral view (*19*) of internal mold of juvenile ventral valve, ×2.

20–23—*Linoproductus ovatus* (Hall). *20,21*, internal and external molds of a somewhat laterally compressed ventral valve, ×1; *22,23*, internal molds of two incomplete dorsal valves, ×2 and ×1.

24–26—*Diaphragmus fasciculatus* (McChesney). ×1. *24,25*, external and internal molds of the same dorsal valve; *26*, lateral view of an incomplete ventral valve.

27–30—Malformation (A), ×10.

31—Malformation (*B*), ×10.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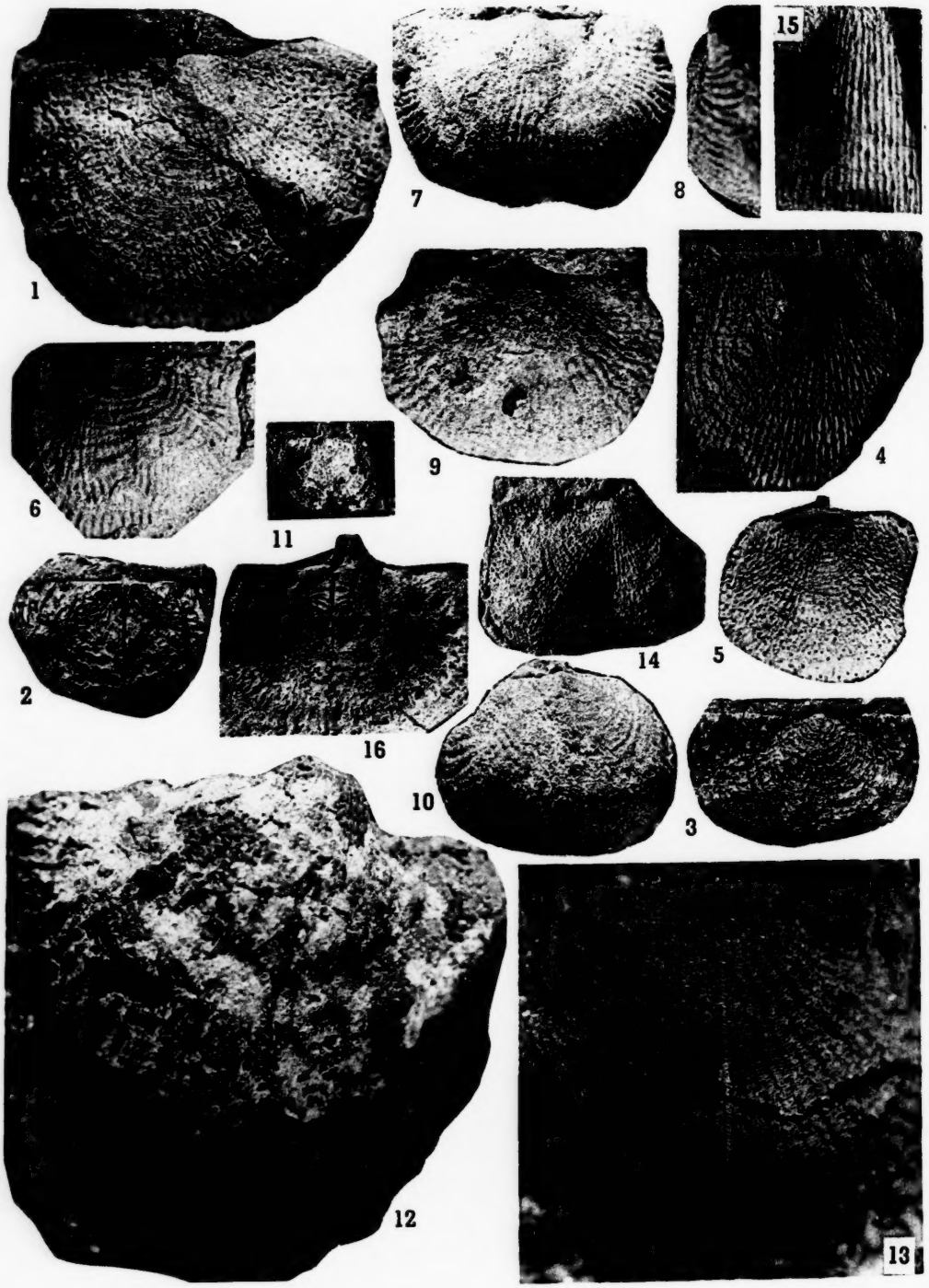
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TABLE 4—MEASUREMENTS IN MM. OF DORSAL VALVE IN GENUS *Diaphragmus*

Specimens	Visceral disk			Same with diaphragm		Suggested classification
	Length	Width	Hinge	Length	Width	
D. elegans, Weller, 1914; pl. XII, fig. 14	7	8		13	15	*D. elegans* s.s.
D. elegans, Hernon, 1935; pl. 81, fig. 26	7	7	8	12	14	*D. elegans* s.s.
D. elegans, Butts, 1926; pl. 65						
fig. 6	9	9.5	8.5	12.5	16	*D. elegans* s.s.
fig. 7	8	9		14.5	19	*D. elegans* s.s.
D. fasciculatus, Girty, 1915; pl. IV, fig. 5						
(*D. elegans* Girty, 1911)	10.5	13.5		16	23	*D. fasciculatus*
D. elegans ?, Girty, 1927; pl. 23						
fig. 22	10.5	14.5		18	22	*D. fasciculatus*
fig. 24	10.5	13		19	24	*D. fasciculatus*
D. elegans Muir-Wood, 1928, pl. II, fig. 1, 2	9	12		12.5	15	*D. fasciculatus*
From Redoak Hollow:						
Spec. pl. 54, fig. 5	9	11.5	15	15	18	*D. fasciculatus*
Spec. pl. 55, fig. 23, 24	10.5	13		14.5	18	*D. fasciculatus*
Nine other specimens	8–10	10–11.5		10–12.5	12–14	*D. fasciculatus*
Spec. pl. 53, fig. 7	6.5	8		8	12	*D. f.* var. *girtyi*, n. var.
Four other specimens	6.5–7	8.5–9		7.5–8	9.5–10.5	*D. f.* var. *girtyi*, n. var.
Spec. pl. 53, fig. 1	8.5	11		9.5	12	*D. f.* var. *bipilus*, n. var.
Three other specimens	7.5–8	10		9–10	11–12	*D. f.* var. *bipilus*, n. var.

enter this identification in a single one of his faunal lists, and in the only lot of collected fossils, where he mentions the species at all, he does it thus: "*Leiorhynchus* is in our collection (lot 5944) associated with a productoid that is probably *Diaphragmus elegans*, though it cannot be definitely so identified."

The illustration of undoubted (as I think) *Diaphragmus elegans* by Butts (1926, pl. 65, fig. 6,7) shows well its diaphragm, muscle impressions, and cardinal area (ibid., fig. 7).

EXPLANATION OF PLATE 56

FIG. *1–5—Buxtonia suttoni*, n. sp., ×2. *1*, external mold of dorsal valve (holotype); *2,3*, internal and external molds of incomplete dorsal valve (paratype); *4,5*, external molds of two dorsal valves (paratypes).

6–10—Dictyoclostus mesialis var. *springerensis*, n. var., ×2. *6*, external mold of dorsal valve (holotype); *7,8*, ventral and lateral views of external mold of dorsal valve (paratype); *9,10*, external molds of two dorsal valves (paratypes).

11—Productus cf. *carbonarius* de Koninck. Outer view of dorsal valve, part of which is exfoliated, exposing its inner mold, ×1.

12,13—Avonia snideri, n. sp. Internal and external molds of holotype, ×10.

14–16—Buxtonia semicircularis (Sutton and Wagner). *14,15*, dorsal valve, external mold of ventral valve showing ornamentation, ×1 and ×2; *16*, dorsal valve, internal mold with molds of *Bascomella* and *Cliona* excavations, ×1.

Judging by this photograph the diaphragm in *Diaphragmus elegans* does not seem to be complex, and thus, in this respect, may be near that in *Productus* s.s.; but this diaphragm is extraordinarily large in comparison with the visceral disk, a feature of distinction which may be as important in the differentiation of *Diaphragmus* from *Productus*, as the complexity of diaphragm.

Thanks to the kindness of Dr. Stoyanow, I have had the privilege of examining in detail the excellent specimen of *Diaphragmus elegans* from the Paradise formation which was described and illustrated by Hernon (1935, pl. 81, fig. 2a,b). It is reillustrated here as text-figures 7,8. It also has an extraordinarily large diaphragm that is almost as high as the visceral disk. Preparatory excavation around the cardinal process in the specimen established its characters typical of the genus and the species, while its trail is as short as in the shells from the Redoak Hollow. It seems that the Paradise example deserves to be differentiated as new variety (A) of *D. elegans*, and the specimen from Alabama, illustrated by Butts, is another example of this variety (text-figure 9).

Species.—The only two known species of *Diaphragmus*, *D. fasciculatus* and *D. elegans*, are so difficult to distinguish one from another that some paleontologists do not consider it practical (Weller, 1914, synonymy on p. 136), while the originator of the genus himself decided in favor of the retention of both species after much deliberation. When he studied *D. fasciculatus* from the Moorefield shale (Girty, 1911), he stated that "though noting certain differences from typical *D. elegans*, I thought it unwise to attempt to distinguish them. After having examined a much larger series of specimens, I now regard it as a distinct though closely related and not always easily separated species. It is a larger shell, more spreading, and has a fairly constant and distinct sinus." (Girty, 1915, p. 57). On the other hand, fasciculation of the costae is concluded to be "only an occasional character, and is not a practicable one for distinguishing this species from *D. elegans*." Weller (1914, p. 138) similarly concludes that "the fasciculate arrangement of the costae is not a conspicuous feature of the species."

DIAPHRAGMUS FASCICULATUS (McChesney)
Pl. 54, fig. 5; Pl. 55, fig. 24–26; text-fig. 10–13

1860. *Productus fasciculatus*, McCHESNEY, Description of new species of fossils from the Paleozoic rocks of the western states, p. 38.
1909. *Productus fasciculatus*, BASSLER, Va. Geol. Survey Bull. 11A, pl. 29, fig. 12,13.
1911. *Diaphragmus elegans*, GIRTY, U. S. Geol. Survey Bull. 439, p. 51; pl. 4, fig. 4,5.
pars 1914. *Diaphragmus elegans*, WELLER, Ill. Geol. Survey, Mon. 1, p. 136–138, pl. XII, fig. 8–11 (only)
1915. *Diaphragmus fasciculatus*, GIRTY, U. S. Geol. Survey Bull. 593, p. 56–58; pl. III, fig. 1–4.
1928. *Diaphragmus elegans*, MUIR-WOOD, Mem. Geol. Survey Gr. Brit., vol. 3, pt. 1, p. 20–23; pl. II, fig. 1,2.
? pars 1928. *Productus carbonarius*, MUIR-WOOD, Id., pl. II, fig. 6 (only)

Description.—Among the numerous remains from the Redoak Hollow referrable to *Diaphragmus* the best is a nearly complete dorsal valve represented by external and internal molds, and a number of less complete dorsal valves which are identified with *D. fasciculatus;* they are somewhat smaller than its known average specimens, but the most complete valve has a median sinus typical for this species. To this species probably belongs an incomplete ventral valve with only a slight indication of sinus, and uneven, apparently partially "fasciculated" costae (pl. 55, fig. 25). The well preserved outer and inner molds of a nearly complete dorsal valve are the main source for the following detailed observations of the external sculpture and of the internal characters, including the cardinal process.

The four successive trails divide the diaphragm into three unequal concentric flanges: the first, innermost flange is the widest, up to 3 mm., in the anterior, and bulges distinctly above the level of the visceral disk; the two outer flanges slope downwards, and decrease progressively in width, which is up to 1¾ mm. in the second and up to 1 mm. in the third flange.

The surface of the sub-quadrate visceral disk is concavo-convex: it is concave for a distance about 4 mm. from the small knob-like beak, while the distant or mature part is gently convex laterally and anteriorly, and gently concave in the antero-lateral corners. The surface is covered by very faint growth

lines and in the mature part by a few irregularly disposed gentle concentric wrinkles; the outer half is also sculptured by radiating costae, which become strong only within the 1 mm. wide sloping anterior edge. A few irregularly scattered circular pits are probably scars of deciduous nodes.*

The cardinal structure consists of two strong horizontal ridges that extend along the length of the hinge line, and a short cardinal process, which produces a slight elevation as it crosses the horizontal ridge. Anterior to the crossing the prologation of the cardinal process spreads gradually as it is divided into three branches: the lateral branches fade out as they approach the gently elevated muscle-scars, while the narrow central elevation grows in height and becomes a prominent narrow median septum that crosses the whole visceral disk and even continues, though as a very faint ridge, over the greater part of the first flange of the diaphragm (pl. 17, fig. 25). Paired muscle scars are sub-triangular, each pair divided into two anteriorly oval loops by a median longitudinal depression.

Cardinal process has the following structure. On ventral side it is smooth and convex, but at its summit it develops a medial furrow and becomes bifid. On the dorsal side its two "barrels" flare open, and the whole process assumes heart-shaped outline, the sharp end pointing downward to the hinge. In the best specimen the muscle scars or openings of the two "barrels" join together downwards, but in other examples their common medial wall descends downward to the hinge as a central vertical callosity, making an impression of a would-be trifid process, which it is not. Completely preserved cardinal process protrudes beyond the plane of the outer side of dorsal valve, so as to enter the overhanging apical part of the ventral valve. The eroded condition of the cardinal process can be recognized by its recession beyond the plane of the outer side of dorsal valve. In these worn examples the process has the appearance of a backwardly reclining, higher than wide, trifid stem.

The specimens may seem smaller than the average valves for *D. fasciculatus*, but no dimensions for its dorsal valve have been published, and the scale of the illustrations of previously published dorsal valves and now measured probably is not exact.

Discussion.—Only a single dorsal valve among those illustrated by Muir-Wood (1928, pl. II, fig. 6) for *Productus carbonarius* de Koninck is here questionably referred to *Diaphragmus fasciculatus* because it cannot be distinguished from the dorsal valves from the Redoak Hollow identified as *D. fasciculatus:* compare it with pl. 53, fig. 7; pl. 54, fig. 5, and pl. 55, fig. 25. The British valve was collected from the Upper Limestone at Garngad Road, Glasgow. The range of *P. carbonarius*, as understood by Muir-Wood, is from "D subzone to Millstone Grit," which certainly includes the beds equivalent to Redoak Hollow and possibly even higher beds.

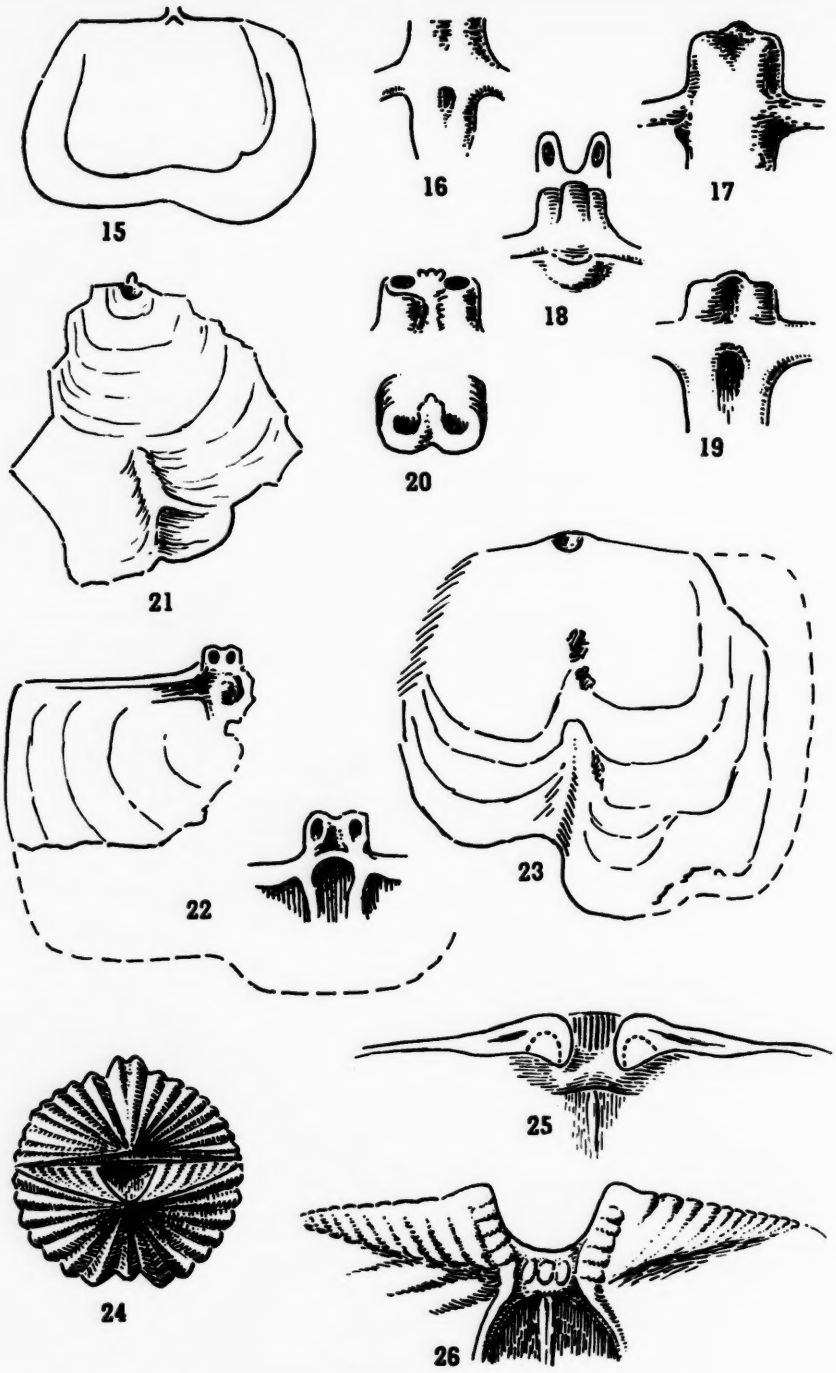
DIAPHRAGMUS FASCICULATUS var. GIRTYI, n. var.

Pl. 53, fig. 7,8; text-fig. 14–17

Description.—The variety thus designated has a dorsal valve only slightly smaller than that in *D. fasciculatus*, with about the same proportion of length to width and about equally developed sinus. It is distinguished from the above described *D. fasciculatus* by a development of a small shallow pit at the base of the cardinal process on the inner side of the valve, and by a different stucture of the cardinal process. The latter is in the form of a short stout column that rises in the plane of the valve, and carries a pair of circular muscular scars at its top, so that they face upwards (distad). This is in contrast with the dorsally facing muscle scars of the cardinal process in *D. fasciculatus*. In var. *girtyi* there is only a slightly indicated medial depression which divides into two "barrels" the very tip of the cardinal process on its ventral side, while on its dorsal side there is a slightly rising medial knob above a shallow linear medial depression (pl. 15, fig. 8,9).

Judging by the location of the muscle scars in the cardinal process of *D. fasciculatus* var. *girtyi* its ventral valve must have

* Raymond (1906, p. 123) observes in the dorsal valve of *Strophalosia truncata* similar "pits which may represent the points of attachment of spines as wherever the spines of the dorsal valve have been detached shallow pits are left in the shell."



TEXT-FIG. *15–26*

15–17—*Diaphragmus fasciculatus* var. *girtyi*, n. var. *15*, external mold of dorsal valve, ×2; *16,17*, dorsal and ventral views of cardinal process, ×10.

18–20—*Diaphragmus fasciculatus* var. *bipulus*, n. var. *18*, dorsal and top views of cardinal process; *19*, ventral view of cardinal process; *20*, ventral and top views of another specimen.

21–23—Malformation A. *21*, external and internal molds, ×10; *22*, ventral view of a squeeze of cardinal process, ×20; *23*, external mold of dorsal valve, ×10.

24–26—*Spirifer casteri*, n. sp. Restored dorsal view of shell, ×2; and internal molds of cardinal area of dorsal and ventral valves, ×10.

overhung the hinge only slightly, its visceral cavity being almost entirely on the ventral side of the dorsal valve, with but very little of the apical part of the ventral valve hanging over the apex of the dorsal valve (see text figure 14 in contrast with text figure 11).

Discussion.—*D. fasciculatus* var. *girtyi* is a transitional form from *D. fasciculatus* var. *bipilus* (described below), and it differs from the latter by having a much smaller and shallower cardinal pit, and a less marked division of the cardinal process into two "barrels" on its ventral side.

The enigmatic sharp depression called "cardinal pit" becomes quite deep in var. *bipilus*. Muir-Wood (1928, p. 18–19) summarizes various observations on "these notches, which occur both in the interior and exterior of the shell" and observes that they "indicate an outlet for some definite purpose, and they may have served as the visceral foramen." Presence of equally strong pit in var. *bipilus* seems to be more than coincidence.

DIAPHRAGMUS FASCICULATUS var. BIPILUS, n. var.
Pl. 53, fig. 1–6; Pl. 54, fig. 6–9; text-fig. 18–20

Description.—The new variety of *Diaphragmus fasciculatus* is differentiated on several dorsal valves only, most of which are represented by external and internal molds, but in two of these the shell of the cardinal area is also preserved. By patient preparatory work the preserved cardinal area was liberated from the matrix without damage to its impression in it, see the photographs of both the molds and the calcareous cardinal areas lifted from them, pl. 53, fig. 1–3.

The variety differs from *D. fasciculatus* as follows: (1) it is slightly smaller though having the same proportion of length to width; (2) its sculpture is fainter; (3) at the base of its cardinal process is a large circular pit, from which extends anteriorly a shallow trough that divides the low and wide anterior extensions of the process; (4) the paired muscular scars are less pronouncedly elevated, and are situated closer to the posterior, their centers about ⅓ the length of the visceral disk (or 2.5 mm.) from the apex; (5) its cardinal process is widely cylindrical on dorsal side, but is divided by vertical central depression into two parallel cylinder-like elevations on ventral side; and (6) two longitudinal depressions (muscle scars) traverse the top ends of these elevations.

D. fasciculatus var. *bipilus* is more like *D. f.* var. *girtyi* in: (1) the development of cardinal pit; (2) the rising of cardinal process within the plane of the valve, while in *D. fasciculatus* it is inclined dorsally, in which direction its depressed muscle-scars face. Var. *bipilus* is slightly larger than var. *girtyi* and is slightly wider than long.

As in the case of the other species and varieties of *Diaphragmus* in the Redoak Hollow, no ventral valve for var. *bipilus* has been found, but some indication of the degree of its convexity is provided by two outer molds (pl. 54, fig. 6–9) of the dorsal valve, which by their size, proportion of length of width, and faint sculpture, seem to belong to the species: they have a well preserved and comparatively large attached trail. The obtuse angle of the trail to the visceral part of the dorsal valves, combined with a clearly indicated gentle curvature along its length permit restoration, by extrapolation, of the curvature of the ventral valve, whose trail must have paralleled closely the trail of the dorsal valve. This extrapolation indicates that its ventral valve has been only moderately curved, that is, it has been far less convex than the ventral valve in *Diaphragmus elegans* and *D. fasciculatus*. The fact that ventral valves are apparently so conspicuously absent in the Redoak Hollow, while the separate dorsal valves of this genus are so abundant seems significant. In the collections of *Diaphragmus* from the upper Mississippian elsewhere, the ventral valves, on the contrary, are usually abundantly represented, and dorsal valves are observed in combination with some ventral valves, usually only when the latter have been broken along the diaphragm. Some ventral valves, which are here classified as *Productus* (?) *matheri*, n. sp., and whose dorsal valves are unknown, could be ventral valves of *Diaphragmus fasciculatus*, or of its var. *girtyi*, but, in not a single one of their inner molds is there

any trace of the presence of a diaphragm, or of inner trails connected with its development. Further collecting from the Redoak Hollow may result in discovery of some undoubted ventral valves of various species and varieties of *Diaphragmus*, but it seems permissible to suggest—and this may help in the search for them—that the ventral valves in the *Diaphragmus* of Redoak Hollow age have been more fragile than its dorsal valves, possibly because becoming thinner when directly attached (cemented to substratum). In the Redoak Hollow, which is its highest recorded geological occurrence, *Diaphragmus* apparently lost its post-mortem ability to hold dorsal valve together with the ventral, and while the ventral valve apparently has lost its durability, the dorsal valve seemingly gained in strength and became very durable.

Brachiopod malformations

Davidson (1861, 1880) designated as malformations asymmetrically developed marginal notches and the corresponding deflections of the growth-lines in British Carboniferous brachiopods. Similar malformations are evident on some isolated dorsal productid valves from the Redoak Hollow. Because none of these valves can be identified with any other brachiopods described here, their malformations could be considered a part of their morphology; and it seemed at first that they could represent an early evolutionary stage toward development of *Keyserlingina* and *Poikilosakos* of Oldhaminidae. Dr. Carl O. Dunbar, with whom I communicated on the matter, disagreed with the opinion and cordially has sent for comparison several excellent brachiopod malformations from the upper Pennsylvanian of Texas, believed to be of same nature as mine from the Redoak Hollow. The new evidence and analysis of the morphology and evolution of Oldhaminidae by Williams (1953) and Stehli (1956) have convinced me that the valves from the Redoak Hollow do not fit well in the Oldhaminid ancestry. Hence the new genus *Pseudokeyserlingina* and its two new species (all *nomina nuda*), in the list of identified invertebrates from the Redoak Hollow (Elias, 1956, p. 87), should be striken out, and the material is here illustrated and described as malformations.

Malformation A

Pl. 55, fig. 27–30; text-fig. 21–23

Two small dorsal valves resemble those of *Diaphragmus*. Their size (5 mm.×6 mm., and 5 mm.×5 mm.) and lack of diaphragms and radial sculpture fit well the young stage in the development of *Diaphragmus*, as seen in its adult valves. It is possible, therefore, that malformations occurred in the young shells and possibly caused the animal's premature death. Absence in the collections of comparable normal young shells of *Diaphragmus* may indicate greater fragility of normal in comparison with malformed shells; the corrugation and the resulting greater callosity could have contributed to their preservation as fossils.

Notches of the malformations are slightly off central position of the anterior, and the side with a notch is slightly smaller than the other side. V-shaped and elevated festooning of the growth lines extends inward one-third to one-half the length of valve, along direction toward its middle, and with gradual diminution of the malformation.

Malformation (A) differs from that in the brachiopods in Dunbar's collection (which may be indicated malformation C) thus: (1) it is elevated instead of depressed (as is the latter); (2) it increases in intensity toward the anterior, instead of decreasing (as in the latter); and (3) it is developed in detached valves, while all malformed brachiopods (C) in Dunbar's collection are complete, tightly clamped shells malformed on both sides: *Linoproductus* sp. *Juresania nebrascensis*, and *Composita subtilita*, all from the Cisco of Texas. Davidson's example of both-sided malformation in a complete and tightly clamped *Productus striatus* from the Carboniferous limestone in Derbyshire (1861, pl. 34, fig. 5,5a) resembles that of Texas shells, except the deeply incised V-shaped malformation has its innermost part slightly turned upward, and the malformation made the shell more pronouncedly asymmetrical than those from Texas.

The causes of the two kinds of malformations were probably different. The clamped shells with malformations on both sides (both valves) were probably bitten by some predator, and survived the bite only for a short time that allowed them to partially heal the wound. The malformation (A) of the detached valves was probably caused by

some disease that gradually intensified and resulted in animal's death.

Malformation B
Pl. 55, fig. 31

The single small (7 mm.×6 mm.) flat dorsal valve from the Redoak Hollow (pl. 55, fig. 31) differs from the other brachiopods in being covered with numerous small erect spines, but no radial ribs. The two barrels of its cardinal process diverge in metrolite-fashion. Malformation is in form of two deep, closely spaced loop-like incisions in postero-lateral region, whose edges are level with the valve. They are like the malformations in the two apparently detached valves of *Streptorhynchus crenistria* from the Carboniferous shale of Scotland illustrated by Davidson (1880, pl. 37, fig. 4,5), except the edges of the innermost parts of the loop-like incisions in the latter are slightly depressed. The valve from the Redoak Hollow and the Scottish valves suffered no diminution in growth of the side affected by incisions, and are fully symmetrical in outline.

The cause of the (B) type malformation seems to be a disease of milder kind than that of (A) type, as it caused no diminution of growth, and has not resulted in premature death, the Scottish malformed valves being mature.

Genus Avonia Thomas

The genus *Avonia* was proposed by Thomas (1914) to include the productid brachiopods with spinose ornamentation in the young stage, changing to costate ornamentation in the adult stage. According to the subsequent emendment of the genus by Muir-Wood (1928) the earlier spinosity on the conch is augmented by costae in the adult stages. It seems that when the American authors began to classify in this genus the local Mississippian productids they added to the characteristic of *Avonia* the presence in the sculpture of its conch of the distinct, subequally spaced "concentric rugae on the posterior portion of the shell" (Sutton, 1938, p. 565).

Avonia (?) spinosa, n. sp.
Pl. 54, fig. 1,2

This species is based on a single dorsal valve represented by its practically complete outer and inner molds. It seems that the valve suffered some mechanical diagonal bend that resulted in strong differentiation of a would-be large ear on its one side only (Plate 16, fig. 1, left upper corner), but discounting this effect the valve is gently concave, and its very small ears are only slightly differentiated by the concave depressions at a very sharp angle to the hinge line. The valve is pronouncedly sculptured by radiating costae, which start very near the protegulum, only 1–1.5 mm. distance from the apex. This small youngest part of the valve is covered with densely spaced lines of growth and a few faint depressions suggestive of deciduous spines. The strong, wide radial costae which cover the rest of the valve increase by intercalation, and are traversed not only by dense lines of growth, but also by a few concentric wrinkles. These wrinkles have little effect upon the costae, that is, the elevation of the costae is not accentuated at the intersection with the wrinkles; but posteriorly to each intersection the linear depression between the costae becomes accentuated, and small pits are thus produced. At the summits of the costae are developed bases of circular spines, but their distribution is not correlated with the development of the concentric wrinkles. The described sculpture seems suggestive of *Avonia*, to which genus the species is questionably referred; the doubt arises from the fact that the interior of genus *Avonia* is poorly known, while the interior of the described dorsal valve is well preserved. It has a strong and narrow marginal ridge very close to the edge of the hinge line along its whole length. Cardinal process is small, divided into two parts by central longitudinal depression on ventral side. A very large cardinal pit lies at the base of the cardinal process, so that only very narrow rims of its expanded base surround the pit laterally. The wall of the deep pit slopes gently anteriorly, and here a low and narrow median septum starts within it, which fades out slightly farther than half way to the anterior. The outer sculpture of the valve is conspicuously reflected on the interior side, except the lines of growth are not reflected.

The valve is subquadrate, 9 mm. long and 10 mm. wide; the hinge is straight, 9 mm. wide. Slightly more than 3 costae occupy 2 mm. at the anterior.

AVONIA (?) SNIDERI, n. sp.
Pl. 56, fig. 12,13

Description.—The development of concentric wrinkles not only in the posterior part of the conch but over all of it, combined with the development of the radial costae also over the whole conch, characterize the shell which is here questionably referred to *Avonia*. Comparison of this form with *Avonia pustulifera* (Moore, 1928, pl. 11, fig. 7,11,12,16,17,20,21; also Sutton, 1938, pl. 62, fig. 12–15) from the Burlington limestone of Missouri leaves no doubt that the form from the Redoak Hollow here designated as *Avonia* (?) *snideri*, n. sp., is its direct descendent, so striking is the similarity of their size, shape, and sculpture. However, there can be noted also certain definite changes in the spacing of the costae and wrinkles, that distinguish the Redoak Hollow form from its predecessor from the Burlington. In *A. pustulifera* there are 6 costae per 5 mm. at the anterior edge of the ventral valve, whose dimensions are 9 mm. high×9 mm. wide. In the ventral valve from the Redoak Hollow which is 8 mm. high×10 mm. wide there are 12 or 13 costae per 5 mm. at the anterior edge. In *A. pustulifera* there can be counted about 10 concentric wrinkles per 1 mm., while in *A. snideri* there are 16 or 17 concentric wrinkles per 1 mm.

Discussion.—*Avonia oklahomensis* (Snider, 1915, p. 83–84, pl. IV, fig. 4–11) from the Mayes formation of Oklahoma is of much larger size (23 mm.×23 mm.) than *A. snideri* or *A. pustulifera*, and has coarser radial costae.

It is difficult to classify *A. snideri* in any other genus than *Avonia*, but perhaps a new genus (related to *Avonia*) could be erected for its reception when more complete material is obtained.

CANCRINELLA BOONENSIS (Swallow)
Pl. 51, fig. 15–17

1859. *Productus boonensis*, SWALLOW, Trans. St. Louis Acad. Sci., vol. 1, 1856–60, p. 217.
1859. *Productus boonensis* var. *elevata*, SWALLOW, *ibid.*
1872. *Productus pertenuis*, MEEK, U. S. Geol. Survey of Nebr. Final Rept. p. 164, pl. 1, fig. 14a-c (not pl. VIII, fig. 9a-d).
1934. *Cancrinella boonensis*, DUNBAR AND CONDRA, Nebr. Geol. Survey, Second Ser., Bull. 5, p. 258–260, pl. XXXII, fig. 1–5.

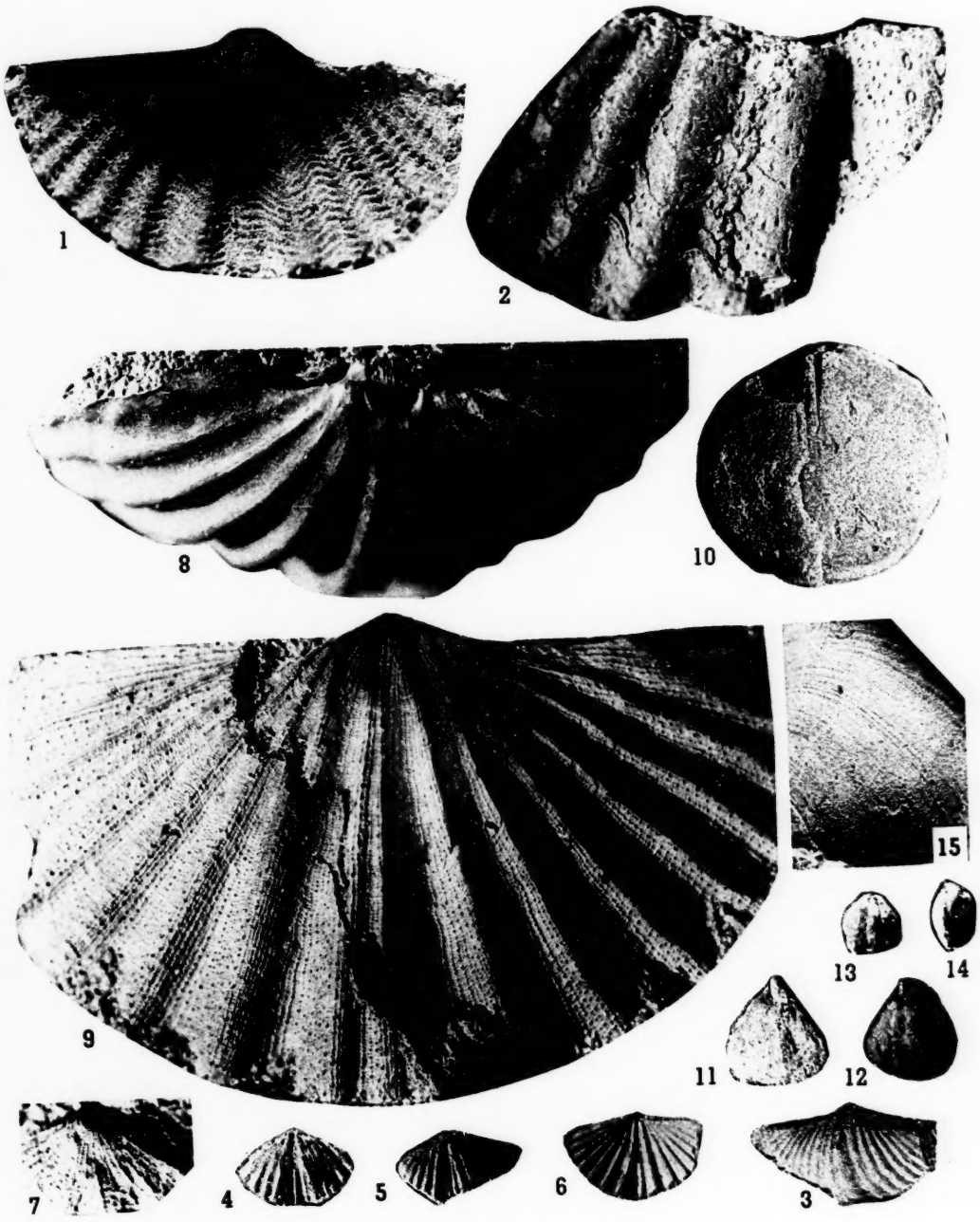
This generally rare species and the only one of *Cancrinella* known in the Pennsylvanian of America, is represented by a number of individuals in the collections. They are all of the size typical for the species, and are unlike the upper Mississippian representative of the genus *Cancrinella moorefieldanus* (Girty) (if referable to *Cancrinella*) from the Moorefield shale of Arkansas, which is nearly twice the length and width of *C. boonensis*, and has much weaker radial costae.

LINOPRODUCTUS OVATUS (Hall)
Pl. 55, fig. 20–23

1858. *Productus ovatus*. HALL, Geol. Iowa, vol. 1, pt. 2, p. 674; pl. 24, fig. 1.
1859. *Productus pileiformis*. MCCHESNEY, Desc. New Pal. Foss., p. 40.
1891. *Productus pileiformis*. WHITFIELD, Ann. N. Y. Acad. Sci., vol. 5, p. 582; pl. 13, fig. 13,14.
1899. *Productus laevicosta*. GIRTY, Mon. U. S.

EXPLANATION OF PLATE 57

FIG. *1*—*Punctospirifer kentuckyensis* (Shumard). External mold of ventral valve, ×10.
2—*Acanthospirina* sp. A. Outer mold of anterior part of middle portion of ventral valve, with the plane of bilateral symmetry in the deeply shadowed plication at the right (holotype), ×10.
3—*Punctospirifer transversa* (McChesney). Internal mold of ventral valve, ×2, (Locality no. 2).
4,5—*Spirifer opimus* Hall. Internal molds of two ventral valves, ×1.
6–9—*Spirifer casteri*, n. sp. *6*, external mold of apical portion of dorsal valve, ×10; *7*, internal mold of dorsal valve, ×2; *8*, posterior view of internal mold of dorsal valve, ×10; *9*, external mold of ventral valve (holotype), ×10.
10—*Composita rotunda* Snider. Internal mold of dorsal valve, ×2.
11–14—*Composita wasatchensis* (White), ×2. *11,12*, internal molds of ventral and dorsal valves; *13,14*, lateral view and dorsal view of juvenile shell.
15—*Composita rotunda* Snider. Part of external mold with external mold of *Ptychocladia* sp., ×10.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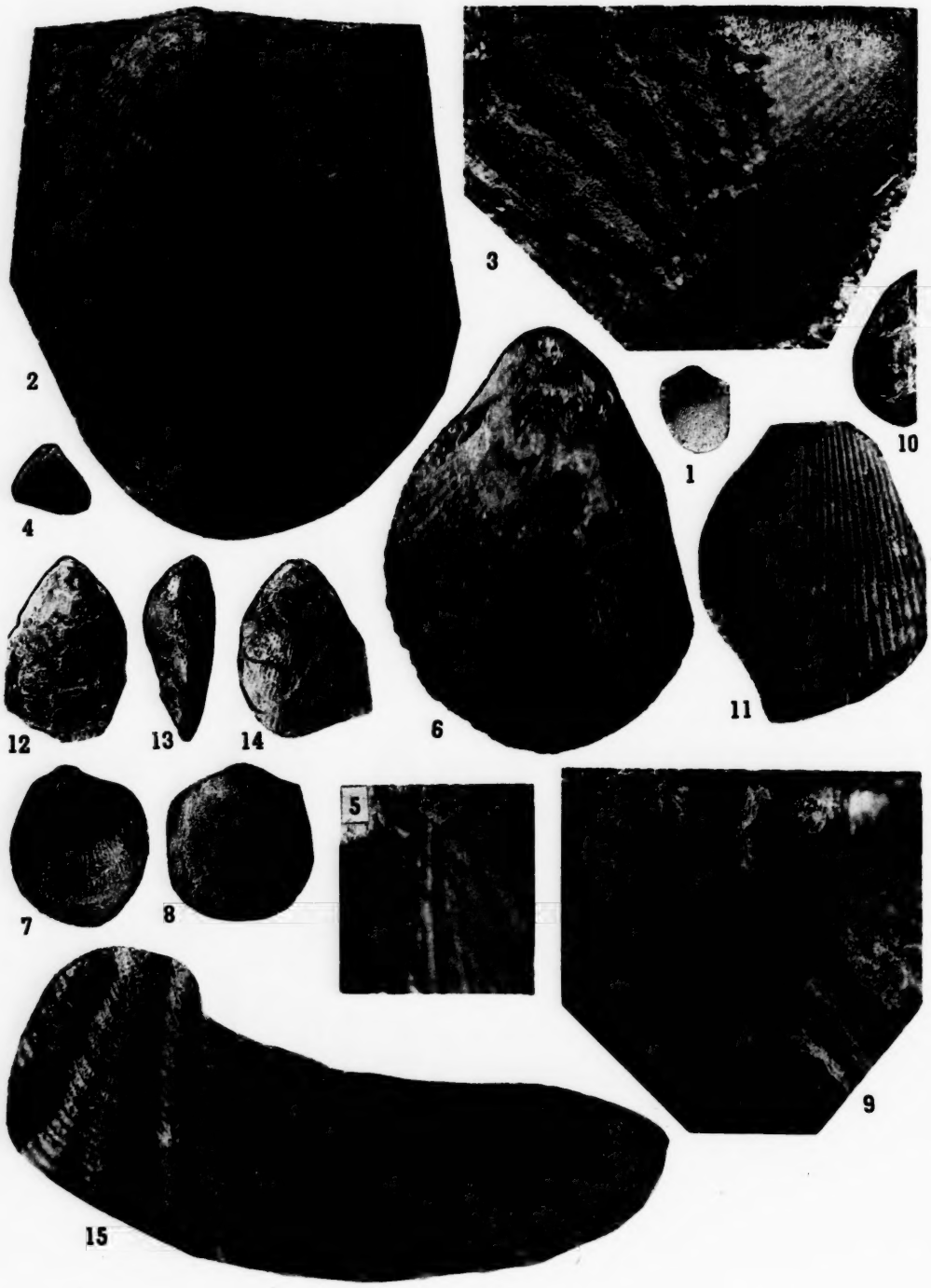
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Geol. Survey, vol. 32, p. 534; pl. 69, fig. 9a-c.

1900. *Productus laevicostus*. WELLER, Trans. St. Louis Acad. Sci., vol. 10, p. 71; pl. 1, fig. 1,2.

1914. *Productus ovatus*. WELLER, Ill. Geol. Survey, Mon. 1, p. 182–185; pl. XVI, fig. 1–15.

1942. *Linoproductus pileiformis*. EASTON, Ark. Geol. Survey, Bull. 8; pl. V, fig. 3,4.

(For a more complete bibliography see Sutton, 1938, p. 558)

Description.—The species is represented in the Redoak Hollow collection by a nearly complete external mold of an early adult stage of the dorsal valve (and an internal mold of a proximal portion of the same), and some incomplete ventral valves of younger individuals. The dorsal valve matches well the photograph of that from the Chester illustrated by Weller, 1914, on pl. XVI, fig. 6,7 but is smaller: 14 mm. long, 16 mm. wide, with concavity of 8 mm. The wrinkles are irregularly distributed, more abundant in posterior part, while the costae are regular and fine, two per 1 mm. in the middle part of the anterior. The internal mold of the posterior part shows a straight hinge about 11–12 mm. long, a very narrow medial septum, and a short tetralobate cardinal process typical of *Linoproductus* (see Sutton, 1943, pl. 53, fig. 16–21).

Discussion.—*L. ovatus* is a very common and variable upper Mississippian form. It is present in the Chester of Illinois and the Pitkin of Arkansas, but not definitely known in the lower Pennsylvanian. Girty lists *Productus cora* in the lower Dornick Hills at Ardmore (see Tomlinson, 1929, pp. 74–75), which broad identification may include forms like *Linoproductus ovatus*. However, the single illustrated specimen of a productid of "*cora* group," (now usually classified as *Linoproductus*) from the upper Morrow of Arkansas illustrated by Mather (1915, pl. VIII, fig. 16–16b) has a decidedly Pennsylvanian aspect, and certainly is not like *L. ovatus*. It is a ventral valve, which is wider than long, while that in *L. ovatus* is longer than wide. Mather suspected that it is probably a species other than *P. cora*, but did not give it a name. It does not seem to match any species of *Linoproductus* recognized in the Pennsylvanian of the Mid Continent by Dunbar and Condra (1938) and other writers, and probably is a new species.

SPIRIFER OPIMUS Hall
Pl. 57, fig. 4,5

1858. *Spirifer opimus*. HALL, Geol. of Iowa, vol. 1, pt. 2, p. 711; pl. XXVIII, fig. 1a,b.

1915. *Spirifer opimus*. MATHER, Denison Univ. Sci. Lab. Bull., vol. 18, p. 185–186; pl. XII, fig. 7–7c.

? 1915. *Spirifer increbescens*. GIRTY, U. S. Geol. Survey Bull. 593, p. 63–65; pl. IV, fig. 7,8 (not *S. increbescens* Hall).

1922. *Spirifer opimus*. MORNINGSTAR, Ohio Geol. Survey, Fourth Ser., Bull. 25, p. 188–190; pl. IX, fig. 13–20.

1932. *Spirifer opimus*. DUNBAR AND CONDRA, Nebr. Geol. Survey, 2nd Ser., Bull. 5, p. 320–322; pl. XLI, fig. 10–11c.

Discussion.—There are a number of small to moderate sized species of *Spirifer* in the late Mississippian and the early Pennsylvanian of America, which are closely related to each other, and the differentiation between

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EXPLANATION OF PLATE 58

FIG. *1,2—Eumetria verneuiliana* (Hall). External mold of dorsal valve: ×1 and ×10.

3—Eumetria sp. Internal mold with punctae of the shell preserved in form of the numerous slender columnar upright; ×10.

4—Eumetria sp. Internal mold of posterior of ventral valve; ×1.

5—Eumetria sp. Internal mold of apical part of ventral valve; ×10.

6–11—Eumetria vera (Hall). *6*, dorsal view of internal mold of juvenile shell; ×10. *8*, external mold of dorsal valve; ×1. *9*, detail of the cardinal area of figure 7; ×10. *10*, posterior view of internal mold of ventral valve; ×2. *11*, internal mold of ventral valve, ×10.

12–13—Eumetria (Acambona?) *deltoides*, n. sp. Ventral, lateral, and dorsal views of holotype; ×1.

15—Punctospirifer transversa (McChesney). External mold of dorsal valve with a few punctae of the shell preserved in form of slender columnar uprights (upper left corner); ×10.

which presents some difficulties. Considerable progress in understanding the distinction between *S. opimus* and *S. rockymontanus*, which at one time have been considered synonymous, has been brought about by Mather (1915, p. 181–186). His conclusion about the validity of both species was verified on different material by Morningstar (1922), and the subject was again investigated and discussed by Dunbar and Condra. They brought about additional clarification in understanding of *S. rockymontanus*, and excluded from it the Morrow form, which Mather so identified, and named it a new species, *S. matheri* Dunbar and Condra (1932, p. 322; Mather, 1915, p. 181–184, pl. XII, fig. 1–6). They also revised and elevated to specific rank, *S. occidentalis* Girty, which Girty at first questionably classified with *S. boonensis* Swallow, but eventually designated as *S. opimus* var. *occidentalis* (Girty, 1927, p. 433, pl. 27, fig. 28–31). These morphologic and taxonomic reviews and revisions added much value to the stratigraphic usefulness of the species, as they revealed that *S. rockymontanus* is a somewhat later Pennsylvanian form, than either *S. opimus* or *S. occidentalis*, only the latter two, but not the former are now known in the Morrow. The present investigation extends the record of *S. opimus* farther down to the Redoak Hollow, where it is rare. Furthermore, it poses a question, whether the species could not possibly originate in pre-Redoak Hollow time. It seems that a small *Spirifer* from the Batesville of Arkansas, which Weller (1897, p. 257, pl. 19, fig. 10–12) identified with *S. keokuk*, and Girty (1915, p. 63–65, p. IV, fig. 7,8) with *S. increbescens*, is closer to *S. opimus*, than to these or any other late Mississippian spiriferids. The attempt of identification with the two mentioned upper Mississippian species was influenced by its stratigraphic position, while its incomplete preservation contributed to uncertainty of the identification. The reported size of the form from the Batesville, with average width of 18 mm. or less, and at most not exceeding 25 mm. (Girty, 1915, p. 64), is substantially smaller than that of either *S. keokuk* or *S. increbescens:* the width of the latter species, measured on ordinary examples from the Chester, is 40 and 44 mm., according to Weller (1914, p. 343), or about two times larger than that observed in the form from the Batesville. Likewise, the number of its plications on either side of the medial sinus and fold is 8 to 10, while the number of same plications in *S. increbescens* is 14 to 18. The corresponding width and count of plications in *S. keokuk* from the Keokuk are more nearly like those in the form from the Batesville, but the latter are closer still, and in fact are practically the same, as in *S. opimus.*

The sculpture of *S. opimus* is about the same as in *S. keokuk* and *S. increbescens*, both concentric and radial lines being present in all, and producing the well known reticulate effect. There seems to be a shade of distinction in the sculpture of *S. opimus*, which is described as consisting of evenly spaced concentric striae, and faint radiating striae (Dunbar and Condra, 1932, p. 321). Presence of this distinction in the sculpture is yet to be verified on the discussed *Spirifer* from the Batesville, which Girty found "not well shown," and described it in uncertain terms (see Girty, 1915, p. 64). In view of this it seems reasonable to designate this form as *Spirifer* cf. *opimus*, that is nearer to the latter than to any other Mississippian or Pennsylvanian species. It is very near the form from the Redoak Hollow, which is here identified as *S. opimus. S. leidyi* is another related form.

Description.—The form from the Redoak Hollow is 26–27 mm. wide, and about 13 mm. high, with ten simple (not bifurcating) lateral plications on either side. The central fold is prominent and the anterior edge consists of four plications (as in the holotype of *S. opimus*). The sculpture is generally reticulate, which is characteristic of the whole group of the discussed spiriferids, but is not clearly that of *S. opimus* type, the radial and concentric lines being equally prominent in the Redoak Hollow material. This is apparently what Girty observes on the form from the Batesville. Although this detail in sculpture is not exactly the same as considered to be typical for *S. opimus*, the small difference hardly invalidates the identification of this species on the Redoak Hollow material but it does bring it closer together with the material from the Batesville. Unfortunately, the sculpture of the material

from the Morrow of Arkansas, which Mather identified with *S. opimus*, has not been described. Hence it is not clear when, in geological time, the radiating lines in *S. opimus* began to lose prominence and the concentric lines to predominate over them, providing their distinction is constant and characteristic for the examples from the higher horizons of the lower Pennsylvanian.

SPIRIFER CASTERI, n. sp.
Pl. 57, fig. 6–9; text-fig. 24–26

1957. *Spirifer casteri* (nomen nudum), ELIAS, Jour. Pal. v. 31; p. 382–383; pl. 40, fig. 1–3.

Description.—This small form is very common in nearly all fossil localities (three out of four) of the Redoak Hollow, and is one of its most characteristic species.

All examples of *S. casteri* are separate ventral and dorsal valves, most of which are broken or incomplete. The most complete adult ventral valve measures: 9.5 to 11 mm. long, 14.5 to 16.5 mm. wide, and with concavity 4 to 6.5 mm.

In no valve could be detected any trace of spiralia, but it can be presumed that these fragile supports were broken off when the valves got separated. Other internal structures are well preserved, see text-fig. 25–26.

There are 7 to 8 lateral plications on either side of central sinus in ventral valve, and on either side of central fold in dorsal valve. Medial sinus starts near beak, and is divided by central fold, which soon divides into two medial folds. At a point slightly closer to beak than to anterior margin, additional folds are added by intercalation on either side, but they do not attain the size of the two medial folds. Principal fold of dorsal valve starts at beak and is divided by central groove into a pair of much elevated medial folds. Additional folds are added by intercalation at about $\frac{1}{3}$ of the length of valve from the beak, but these do not attain the prominence of the two medial folds.

Discussion.—The above described *S. opimus*, a rare form from the same localities, differs from *S. casteri* in smaller number of lateral plications; their number is 7 or 8, and they are quite stabilized in *S. casteri*. Another distinction is greater prominence of the fine, reticulate sculpture, and possibly also the fan-like divergence of the radial lines in the troughs between the plications. The latter detail makes the sculpture in *S. casteri* so strikingly similar to that in *Meekella striatocostata* that fragments of the two forms can be easily confused. The sculpture of *M. striatocostata* illustrated in the enlarged photograph by Dunbar and Condra, 1932, pl. XVI, fig. 10, can be matched easily by the sculpture in *Spirifer casteri*, see plate 19, figure 9. Unfortunately no comparable information on such fine details is available for the sculpture in *Spirifer opimus*, *S. rockymontanus*, *S. increbescens* and other common and stratigraphically important spiriferids. Most complete is the descriptive information on the sculpture of *S. rockymontanus*, which consists of "fine radial lirae, which are crossed by about equally spaced, sharp, concentric lirae, the two sets of lines tending to form nodes at their intersections" (Dunbar and Condra, 1932, p. 319). This is exactly the kind of sculpture in *S. casteri*, where the intersections of the two sets of lines are produced into small mucros. However, in the available shells of *S. rockymontanus* from central Colorado it was not possible to find any divergence of radiating lines in the troughs between the plications. Furthermore, its radial lines tend to disappear along the crests of plications and all along the anterior, where the concentric lines alone make a shingle-like sculpture.

Spirifer casteri resembles closely *Spirifer parvus* Sutton and Wagner from the Chester series (Paint Creek formation and Cypress sandstone) of Kentucky, and could be considered its variety but for its much larger size and larger number of lateral plications. It is up to 18 mm. wide and up to 10 mm. high, that is nearly twice as large as *S. parvus*. It has 7 to 8 lateral plications, while *S. parvus* has only six.

Sutton and Wagner (1931, p. 30) describe the sculpture of *S. parvus* thus: "In addition to the plications, the surfaces of both valves are marked by fine, radiating striae, fine sublamellose concentric markings, and stronger concentric lines of growth which are crowded toward the anterior margin." This is much the same sculpture as developed in *S. casteri*, except in the latter the radiating and concentric "striae" are of equal strength and produce reticulate pattern, with tiny spines at their intersection—a type of sculp-

ture not mentioned by Sutton and Wagner, and perhaps not as clearly indicated in *S. parvus* as in *S. casteri*, or not well preserved, or both. Doubtlessly *S. casteri* has evolved from *S. parvus*, the evolutionary trend being toward larger size and possibly toward greater regularity in the spacing of radial and concentric sculpture.

Punctospirifer kentuckyensis (Shumard)
Pl. 57, fig. 1

1852. *Spirifer octoplicatus*. HALL, in Stansbury's Salt Lake Rep., p. 409, pl. XI, fig. 4a,b (not *S. octoplicatus* Sowerby, 1827).
1855. *Spirifer kentuckyensis*. SHUMARD, Mo. Geol. Survey, An. Rep., p. 203,
1856. *Spirifer kentuckiensis*. HALL, Pacific Railroad Rep. vol. 3, p. 103; pl. II, fig. 10,11.
1866. *Spirifer laminosus*. GEINITZ, Carb. and Dyas in Nebr., p. 45; pl. III, fig. 19a-d.
1872. *Spiriferina kentuckyensis*. MEEK, U. S. Geol. Survey Nebr., Final Rep., p. 185–186; pl. VI, fig. 3a-d; pl. VIII, fig. 11a,b.
1932. *Punctospirifer kentuckyensis*. DUNBAR AND CONDRA, Nebr. Geol. Survey, 2nd Ser., Bull. 5, p. 351–355; pl. XXXVIII, fig. 1–5 (not *S. laminosus* McCoy, 1944).

Description.—The two specimens from the Redoak Hollow are dorsal molds of valves, one of which is somewhat distorted and not quite complete. However, the details of this material are so well preserved that there is no doubt in identifying it with *P. kentuckyensis*. The dimensions of the restored dorsal valve are: length 7 mm., width 14 mm., convexity 3.5 mm., width of medial fold at the anterior edge 6 mm. There are six subangular lateral plications on either side, which are subequal and do not diminish greatly in width toward the sharp lateral terminations. External sculpture consists of sharp, subequal, shingle-like concentric laminations, which arch strongly when passing over the crests of the plications. No spines have been observed on the fragment of the external surface, which represents the medial part of the anterior portion of the valve. The shell substance is coarsely punctate, which is demonstrated by the ferruginous casts of the delicate tubules, which stand upright attached to both external and internal molds of the valve.

Discussion.—The characteristic species of the Chester, *Punctospirifer spinosa* Norwood and Pratten, is very close to *P. kentuckyensis* in shape, size, and character of plications, but differs by quite different sculpture: the shell is covered by "spinules, which are scattered in position, or sometimes are arranged in rather irregular radiating rows" (Weller, 1914, p. 300). Even when these spines are not well preserved, their position is indicated by tubercles. As to the concentric sculpture, this is indicated only by "one or more strong lines of growth . . . " sometimes present toward the anterior margin of the valves" (Weller, 1914, p. 300). The material from the Redoak Hollow decidedly has a sculpture of *P. kentuckyensis*, and not of *P. spinosa*.

The differences between the two species were clearly understood by Girty, as he discussed the occurrence of *P. spinosa* in the Batesville of Arkansas (1915, p. 67); hence, his identification of *Spirferina* aff. *spinosa* in the Otteville (Jolliff?) limestone at Ardmore (Tomlinson, 1929, p. 75) is an interesting evidence of a survival of a form related to this species in the basal part of the upper Morrow; but in the higher beds of the Lower Pennsylvanian in Ardmore Basin Girty identifies consistently only *Spiriferina kentuckyensis* (Tomlinson, p. 73–74).

PUNCTOSPIRIFER TRANSVERSA
(McChesney)
Pl. 57, fig. 3; Pl. 58, fig. 15

Discussion.—Several fragmentary and one satisfactorily preserved complete valve of this spiriferid prove its existence in the Redoak Hollow. There are four species of *Punctospirifer* (*Spiriferina* of author's) which are known in the Chester and lower Pennsylvanian rocks of the Midcontinent, and recognition of the differences between them is stratigraphically important. They are *P. transversa*, *P. spinosa*, *S. campestris*, and *S. kentuckyensis*. The first two are eminently Mississippian and the last two Pennsylvanian forms. *P. transversa* is distinguished from the other three species by its transversely elongated shell, which is "more than twice as wide as long" (Weller, 1914, p. 298). Presence of this species in the Morrow of Arkansas was already established by Mather, and therefore its occurrence in the Redoak Hollow could be anticipated. There seems to be no practical way of separating the Morrow specimens from the Chester form (Mather, 1915, p. 193), and the present observation of the form from the Redoak Hollow confirms this conclusion.

Girty and Roundy (1923) do not list *S.*

transversa among the identified forms in the lower Dornick Hills of Ardmore Basin, but record only *Spiriferina* aff. *spinosa* in the Otterville (Jolliff?) (Tomlinson, 1929, p. 75), and *Spiriferina kentuckyensis* in the undoubted Otterville (ibid., p. 79). Girty's familiarity with the species of *Punctospirifer* leaves no doubt as to the correctness of his specific identification of the forms of this genus, and when collecting at Ardmore Basin I also was not able to find it in the beds higher than the Redoak Hollow. Hence locally *S. transversa* probably disappeared at the end of the Redoak Hollow time, though survived into late Morrow in western Arkansas and adjacent part of Oklahoma.

Genus ACANTHOSPIRINA
Schuchert and Le Vene

1855. *Spirifer*. NORWOOD AND PRATTEN, pars, Jour. Acad. Nat. Sci., Philadelphia (2), vol. 3, p. 71.
1883. *Spiriferina*. HALL, pars, Rep. N. Y. State Geol. for 1886, pl. (35), 60, fig. 26–29.
1893. *Spirifera*. ROWLEY, pars, Am. Geol., vol. 12, p. 307.
1908. *Spiriferina*. ROWLEY, pars, Mo. Bureau Geol. and Mines, vol. 8, 2nd ser., p. 84.
1908. *Spiriferina*. GIRTY, pars, U. S. Geol. Survey Prof. Pap. 58, p. 372.
1914. *Acanthospira*. WELLER, Ill. Geol. Survey, Mon. 1, p. 418.
1914. *Spiriferina*. WELLER, pars, ibid., p. 299; *S. spinosa* only.
1929. *Acanthospirina*. SCHUCHERT AND LEVENE, Am. Jour. Sci., 5 ser., vol. 17, p. 119.
1930. *Acanthospirina*. KING, Univ. Texas Bull. No. 3042, p. 121–122.
1943. *Acanthospirina*. WILLIAMS, U. S. Geol. Survey Prof. Pap. 203, p. 84–85.

This rare genus was differentiated by Weller upon a single species originally described by Rowley (1893, p. 307, pl. 14, fig. 13–14; 1908, p. 84, pl. 18, fig. 13–15), first as *Spirifer* and later as *Spiriferina aciculifera*. Weller disagrees with this classification because the shell structure in the species "is apparently non-punctate and there is no evidence of a median septum in the pedicle valve" (Weller, 1914, p. 418). To explain Weller's observation of the non-punctate shell structure, it is well to point out that, in view of the minute size of the generotype (4 mm. × 5.6 mm.) and the fact that the shell substance in the genus *Spiriferina* is usually "finely and closely punctate," the punctae in *A. aciculifera* could have been overlooked. Weller realized this possibility for he stated that the shell substance is "apparently" nonpunctate. Occurrence of a form in the Redoak Hollow undoubtedly closely related to *A. aciculifera* but much larger and with distinctly punctate shell structure casts doubt on the statement by Weller and suggests a punctate shell for *A. aciculifera*, though its punctae are probably exceedingly minute and confined to the inner layer of the shell substance (compare the observations by Girty, 1908, p. 372). The second distinction of *A. aciculifera* from genus *Spiriferina* mentioned by Weller is inferred rather than real, as he states that "the internal characters of the pedicle valve are not clearly defined because of the complete retention of the shell substance," the observations of the interior being made by looking through the "sufficiently transparent" shell. Thus, as he observes, "no medium septum is apparent and is probably wanting in the species" (Weller, 1914, p. 419).

There remains only peculiar surface ornamentation among those characteristics that differentiate *Acanthospirina* from *Spiriferina* and other related genera, but it may be considered sufficiently important for retention of this genus. It seems equally distinct from either of the two groups into which Girty (1908, p. 371–374) divides genus *Spiriferina:* one is typified by *S. spinosa*, and is characterized chiefly by the absence of equidistantly spaced concentric lamellae, ornamentation by relatively large spines, and little distinction of the mesial sinus and fold from the few lateral folds; the other is typified by *S. transversa*, and is characterized by equidistantly spaced concentric lamellae, ornamentation by delicate hairlike spinules (in varying abundance and arrangement), numerous lateral folds, and strongly specialized mesial sinus and fold, which are frequently complicated by a small additional fold and sinus within them. In a comprehensive discussion Girty (1908, p. 372) considers the possibility that the early Mississippian stock represented by "*Spiriferina aciculifera* and *S. schucherti*" gave rise to the *S. spinosa* group of the later Mississippian and succeeding periods of time, but hesitates to commit himself on this point because "it is not known whether they are septate and punctate." At least the last of the two characters is being established for *Acanthospirina* from the Redoak Hollow,

which evidence brings the phyletic relationship of this genus closer to *Spiriferina* generally, but does not necessarily prove that *Acanthospirina* stock is ancestral to it, even if the former makes its appearance earlier (in basal Mississippian) than the earliest record of *S. spinosa* group. *S. schucherti*, which Girty puts in a group with *A. aciculifera* belongs in the *S. spinosa* group, as its scattered spines are not arranged in rows along the crests of the folds. Hence *Spiriferina* and *Acanthospirina* seemingly diverged from each other before the earliest Mississippian time and survived through it as two independent, well defined stocks.

The new form from the Redoak Hollow is similar to *A. aciculifera* in all respects, except being about three times larger. Its shell is decidedly punctate and also ornamented by regularly arranged spines, the strongest lined up along the crests of the folds. This new evidence seems strongly indicative that the shell in *S. aciculifera* is also punctate. If so, the brief diagnosis of genus *Acanthospira* could be formulated as follows:

Shell spiriferid in form and probably like Spirifer in the internal characters. Surface ornamented by very fine concentric lines of growth and numerous smaller spines, and also by larger spines arranged in radiating rows along the crests of some folds and of the mesial sinus. Inner layer of the shell substance perforate. Interior characters poorly known.

ACANTHOSPIRINA sp. A.
Pl. 57, fig. 2

Description.—Only one external mold of a fragment of a pedicle valve is recovered, but its sculpture is so well preserved and so much like that in *A. aciculifera* that its classification with *Acanthospirina* seems reasonably certain. Thanks to the preservation of a small fragment of the internal mold attached to the external mold of the same valve the delicate hair-like molds of the "punctae" of the shell stand out upon it, and thus furnish new evidence toward the establishment of the character of the shell substance and cause the emendation of the diagnosis of the genus, see under genus *Acanthospirina* above.

As the posterior of the valve is preserved, including more than half the width of the mesial sinus, it is possible to extrapolate from the measurement of the preserved part and restore the total width of the valve, which must have been 15 or 16 mm., and height probably near 7 mm. Mesial sinus 2½ or 3 mm. at the posterior edge. Seven (or possibly eight) lateral folds on each side of the sinus.

Surface ornamented by fine concentric lines of growth, 17 or 18 per 1 mm., a few of which become coarser and laminose (shingle-like) in the late mature part of the valve. Numerous spines are scattered with even density over the entire surface, their bases elongated radially. Slightly larger spines form single radial rows upon the crests of folds except on the two folds nearest the mesial sinus; along the crest of the fold second from the sinus they form a somewhat irregular double row, and along the crest of the first fold only ordinary small spines are scattered. A single row of larger spines is arranged along the middle of the bottom of the mesial sinus. Concentric rows of small, densely spaced spines appear between some of the coarser shingle-like transverse plications in the late mature part of the valve.

Discussion.—The form differs from *A. aciculifera* in being nearly three times larger and in details of ornamentation. Its size near that of *A. spinosa* (Weller, 1914, p. 299–300, pl. XXXV, fig. 50–58), but the spines in the latter species are of uniform size over all the surface and show a tendency toward radial arrangement, none producing special rows along the crest of the folds, or along the bottom of the sinus.

Genus COMPOSITA
COMPOSITA ROTUNDA Snider
Pl. 57, fig. 10,15

1915. *Composita rotunda.* SNIDER, Okla. Geol. Survey, Bull. No. 24, p. 2, p. 98–99; pl. V, fig. 25–28.

Description.—A single dorsal valve, represented by well preserved external and internal molds, is referred to this upper Mississippian species with considerable degree of certainty. Its size, outline, and surficial ornamentation are practically identical with those in the dorsal valve of Snider's species from the Mayes of Oklahoma, while the internal molds of the shell in the Redoak Hollow add to the knowledge of its inner structure not originally observed by Snider.

The dorsal valve is 19 mm. high and 21

mm. wide, subpentagonal (to nearly circular) in outline, the 11 mm. wide truncation caused by the broad and faintly differentiated anterior fold. The fold is opposite the equally broad sinus of ventral valve, "originating at or in front of the middle of the valve, widening very rapidly, very shallow and ill-defined, produced into a lingual extension, emarginating the anterior outline of the brachial [dorsal] valve" (Snider, 1915, p. 98).

The well preserved external mold of *C. rotunda* from the Redoak Hollow shows that the ventral valve is covered throughout by very delicate concentric lines of growth, and by occasional concentric lamellae, or what Dunbar and Condra (1932, p. 365) term "sub-lamellose varices of growth." They are shingle-like, the additional concentric layers of the shell substance being added under the earlier ones. This shingle-like overlap is usually slightly more conspicuous in the lateral than in the medial portions of the conch.

When viewed in tangential light there can be seen in the Redoak Hollow internal mold some very faint radial striae, a feature generally observable on the interior of the shells in genus *Composita*, which seems due to the fibrous structure of its shell substance (see the remarks by Dunbar and Condra, 1932, p. 326). In the cardinal area of the mold there is a strong medial septum, wedge-shaped in cross-section, extending for 7 mm. or about $\frac{1}{3}$ of the length of the shell from the subdued beak. It extends some 4 mm. farther, near the middle of shell, in form of a very faint linear elevation. Faint and low lateral ridges are indicated in subparallel position at a distance of about 1 mm., one on either side of the median septum. A pair of widely diverging low ridges extend also from the beak, about 4 mm. long each, and nearly parallel to the cardinal edge of the conch. The subquadrate cardinal plate lies in the plane of contact between the valves, its central triangular depression facing ventral valve; it is bordered on either side by buttress plates, which diverge anteriorly, are laterally concave, and support on their inner (dorsal) side the short crural plates.

To this species probably belongs an internal mold of a ventral valve, which is distorted by a shearing displacement along a crack, which splits the beak longitudinally and then extends across the rest of the valve diagonally. Judging by the conspicuous, incisor-like interior mold of the beak, it was fairly prominant; inside of it is a pair of parallel narrow dental plates, which subside greatly anteriorly, and fuse into a broad arch, thus outlining a deep oval depression, into which fits the cardinal process of the dorsal valve. The anterior border of the depression extends into a low and long, gradually wedging out elevation to about a center of the shell, and from there and to the anterior edge of the shell extends merely a low, crest-like elevation, formed by the opposite slopes of a pair of broad and shallow longitudinal depressions. The whole mold resembles the internal mold of a pedicle (ventral) valve of *Cliothyridina parvirostris* (Meek and Worthen) from the "residual chert" at Springfield, Missouri, and illustrated by Weller (1914, pl. 78, fig. 25). Perhaps the latter species, which characterizes the Keokuk of Illinois, is an ancestral form of *Composita rotunda* of the Mayes, which may be a geologically younger form.

The external mold of the dorsal valve of *Composita rotunda* bears a very delicate ferruginous mold of the boring sponge *Cliona paleodendrica*, n. sp.

Discussion.—The anterior localization of the faint medial fold in the dorsal valve is the decisive feature in the identification of the species from the Redoak Hollow with *C. rotunda* rather than with the very closely related and stratigraphically younger *C. ovata*. The latter was originally described from the Morrow of Arkansas by Mather (1915, p. 202–203, pl. 14, fig. 6–6c), and later recorded from higher formations up to the Wabaunsee, that is nearly to the top of the Pennsylvanian (Dunbar and Condra, 1932, p. 370–371, pl. 43, fig. 14–19). Judging by the illustration in Snider (1915) *C. rotunda* is 25 mm. high and 24 mm. wide, while the corresponding dimensions of *C. ovata*, as measured by Mather (1915, p. 202), are 27.3×26.8 mm., and 21.8×18.0 mm., the proportion of height and width being about the same; about the same proportion is observed in higher Pennsylvanian examples illustrated by Dunbar and Condra. An important innovation in the Pennsylvanian species as compared with *C. rotunda* is the development of the medial fold throughout the dorsal valve with almost uniform width

at the posterior as well as in the anterior parts of the valve. In connection with the growing prominence of the fold in later Pennsylvanian time, the outline of the anterior tends to become slightly attenuated, the effect being created by the two flanking latero-anterior concavities, see Dunbar and Condra, 1932, pl. 43, fig. 19, and, particularly, fig. 14b; the feature is not developed in the type of *C. ovata* from the Morrow, compare Mather, 1915, pl. 14, fig. 6,6a.

Another feature of distinction between *C. rotunda* and *C. ovata* is the development in the ventral valve of the latter of a narrow and sharply differentied sulcus in the bottom of the broad medial sinus, see Mather, 1915, pl. 14, fig. 6a. Because no adult ventral valve of *C. rotunda* was collected from the Redoak Hollow, presence of this sulcus in the shells from this formation cannot be ascertained. As the development of a sinus in the ventral valve and of a corresponding fold in the dorsal valve is known to be interconnected in known examples of Athyridae, it seems likely that the sulcus is absent in *C. rotunda* from the Redoak Hollow, as it is definitely known to be absent in the type of this species from the Mayes.

COMPOSITA WASATCHENSIS (White)
Pl. 57, fig. 11–14

1874. *Rhynchonella wasatchensis*. WHITE, Prelim. Rep. Inv. Foss., p. 19.
1877. *Rhynchonella wasatchensis*. WHITE, U. S. Geol. Survey, W. 100th Merid., vol. 4, p. 130; pl. 9, fig. 3a-d.
1899. *Composita humilis*. GIRTY, U. S. Geol. Survey, Mon. vol. 32, pt. 2, p. 565; pl. 71, fig. 6a-c.
1911. *Composita* aff. *humilis*. GIRTY, U. S. Geol. Survey, Bull. 439, p. 77; pl. IV, fig. 8,9 (?).
1915. *Composita wasatchensis*. MATHER, Denison Univ. Sci. Lab. Bull. vol. 18, p. 200–201; pl. XIV, fig. 7–10b.
1928. *Composita humilis*. GIRTY, U. S. Geol. Survey, Prof. Paper 152; pl. 22, fig. 38,39.

Description.—This is perhaps the smallest species of *Composita;* it is characterized, besides the small size, by the circular outline of its dorsal valve, and a faint medial sinus on ventral valve and corresponding fold on dorsal valve. The posterior of the ventral valve is only slightly attenuated, which causes a subtriangular outline of this part of the shell and accounts for its slightly longer than wide dimensions.

The measurements of the largest shells from the Redoak Hollow are 9 mm. long, 8 mm. wide, and 5.5 mm. thick, the thickest part is posterior to the middle of the shell. The surface is not well preserved due to the fragility of the fibrous substance of the shell, but the slight indication of medial sinus and folds are noticeable as they are reflected in the interior of the shell.

Discussion.—Dunbar and Condra minimize the close resemblance of the form from the Morrow, which Mather identified as *C. wasatchensis* to the original species described by White, and consider that Mather's *C. wasatchensis* is conspecific with his *C. ovata*, being its young (Dunbar and Condra, 1932, p. 370–371). The latter species, thus broadly understood, has been identified by Dunbar and Condra throughout the Pennsylvanian of the Mid Continent. However, the material from the Redoak Hollow gives support rather to the narrower understanding of *C. wasatchensis*, which is eminently a smaller form, and whose stratigraphic range would thus be limited to the Upper Mississippian and the Morrow. At any rate, the examples from the Redoak Hollow are closer to those described and illustrated by Mather (1915) as *C. wasatchensis*, but not to those which he, and also Dunbar and Condra identified as *C. ovata*. On the other hand, the form from Redoak Hollow approaches also the smaller specimens of *C. humilis* from the Moorefield and the Madison, which were described by Girty.

Genus EUMETRIA Hall

Description.—The material from the Redoak Hollow adds little to the knowledge of this easily recognizable genus, whose differentiation was elucidated by Weller (1914, p. 437). Most characteristic is the subcircular shape of the moderate to small size shells, and their sculpture, which consists of a number of very regular radiating costae that never bifurcate, but run without increase in number from the cardinal area to the anterior, each costa gradually increasing in width. The costae (called by some authors plications) are broadly convex, and are separated from each other by narrow, angular depressions. The shell substance is longitudinally fibrous and minutely punctate; the internal tubules, which terminate

in the punctae, are oriented perpendicular to the surface of the conch, and are arranged in regularly spaced and regularly intersecting diagonal rows, with about ten tubules per 1 mm. in a row.

Discussion.—There are two schools of thought in regard to the differentiation of the Upper Mississippian species in *Eumetria*. The more conservative view is held by Girty (1915-A, p. 75) who recognizes only one species, *Eumetria marcyi* Shumard, while Hall, Weller, and most subsequent writers recognize many. Three of these, *E. vera*, *E. verneuiliana*, and *E. costata*, Girty throws into the synonymy of *E. marcyi*. All three were introduced by Hall, two as species, and the third as a variety, which was subsequently elevated to specific rank by Weller. Besides, additional new species were described from the Chester and its equivalents by S. Weller (1914) and Snider (1915).

Admitting the difficulty of differentiation between the species, and the probability of existence of intermediate forms between them, which could have influenced Girty's conservative attitude and his belief that the observed differences are rather of individual nature, and not even of varietal rank—it appears that it is, at least, stratigraphically useful to recognize the species on the grounds indicated by Hall, Weller, and their school of thought. Unfortunately the existence of both broader and narrower understanding of the species in *Eumetria* causes some taxonomic confusion.

Girty's conservative attitude led him to accept Shumard's species *E. marcyi*, admittedly poorly described and illustrated. Nevertheless, under the wide understanding of the species, it would undoubtedly include all the species that were subsequently differentiated by Hall, and all of which therefore would become its synonyms. When species of *Eumetria* are recognized in narrow sense, all species erected by Hall become valid. Furthermore, as Weller points out, it becomes uncertain, which of them is identical with *E. marcyi* Shumard because its imperfect original description and illustration and the loss of types make it impossible to compare the various details on which the narrow species are recognized. Because *E. marcyi* is nearest to *E. costata* in the number of costae (or plications), as Weller states, the former species name can be used instead of the latter, as it certainly has a priority over it; but, as he advises, "considering the uncertainty which must exist in the absence of the type specimens, as to what *E. marcyi* really is, it seems best to drop that name altogether and to use the names applied by Hall, which were clearly defined and were illustrated by excellent figures" (Weller, 1914, p. 444).

In the material of genus *Eumetria* from the Redoak Hollow, which is nearly always variously damaged, two species erected by Hall, *E. vera* and *E. verneuiliana*, and a new species *E. deltoides* seem to be recognizable. Besides, the form from the upper Morrow of Arkansas, which Mather identified with *E. vera*, is here considered a new species, *E. matheri*, new name.

EUMETRIA VERA (Hall)
Pl. 58, fig. 6–11

1859. *Retzia vera*. HALL, Geol. Iowa, vol. 1, pt. 2, p. 704, pl. 27, fig. 3a.
1894. *Eumetria vera*. HALL AND CLARKE, Int. to Study of Brach., pt. 2; pl. 37, fig. 8,12. 1895. HALL AND CLARKE, N. Y. Pal., vol. 8, pt. 2; pl. 51, fig. 36,37. BASSLER, Va. Geol. Survey, Bull. No. II A; pl. 29, fig. 4,5. 1914. WELLER, Geol. Survey Ill., Mon. 1, p. 444–445; pl. LXXVI, fig. 13–17. 1915. SNIDER, Okla. Geol. Survey, Bull. No. 24, p. 94. 1931. WELLER, Ky. Geol. Survey, Symposium, p. 265; pl. 38, fig. 7a,b. 1935. HERNON, Jour. Pal., vol. 9, p. 688; Not 1915. MATHER, Denison Univ. Sci. Lab. Bull., vol. 18, p. 197,198; pl. XII, fig. 14–14b (*E. matheri*, n. sp.); Not 1942. EASTON, Ark. Geol. Survey Bull. 8, p. 85; pl. VII, fig. 11, (=*E. costata*).
1915. *Eumetria marcyi*. GIRTY, pars, U. S. Geol. Survey, Bull. 593, p. 75–77; pl. IV, fig. 19–19b (only).

Description.—In the material from the Redoak Hollow the number of the costae at the distance of 20 mm. is 5 per 5 mm., and the total number of the costae is near 46 or 48, which is within the variability of the species established by Weller (1915, p. 445). The valves from the Redoak Hollow are subcircular, the largest ventral valve measuring about 22 mm. long and 22 mm. wide. Its convexity is 5.5 mm., and the hinge measures also about 5.5 mm.

Discussion.—*E. vera* and *E. verneuiliana* are nearer to each other than any other recognizable species of the genus. Weller (1914, p. 445) states that the former differs

from the latter "in attaining a larger size, in having a somewhat smaller maximum number of plications, and in the more anterior position of the greatest width of the shell." In view of the damaged condition of all *Eumetria* material from the Redoak Hollow, the total number of costae (plications), which is important diagnostically, can be seldom counted with complete assurance. Therefore an attempt is here made to add to the characteristics of the discussed species of *Eumetria* the number of costae per given space (5 mm.) and counted at a distance of 10 mm. and 20 mm. from the beak of ventral valve. Because the costae of the genus are very regularly disposed and do not bifurcate or increase in number of intercalation as the shell grows, the width of each costa is regularly increasing with growth of shell while their number per given space is correspondingly decreasing. Because of this each species is found to have a characteristic measurement or count, which is numerical way of expression of the degree of coarseness or fineness of the sculpture (not meaning the height of elevation of the costae above the surface of the shell, however). In *E. vera* illustrated in the photographs by Weller (1914), the number of costae at the distance of 10 mm. is 8, and at the distance of 20 mm. is 5 per 5 mm. or slightly more, and attains 4.5 at the distance of 26 mm. at the anterior edge.

Among the forms previously identified as *E. vera* the following are excluded here from this species. The specimen illustrated by Mather (1915, pl. XII, fig. 14–14b) is much smaller than *E. vera* and it could be hardly a juvenile specimen of this species, as the photographs show finer costae than as typical or *E. vera* at a given distance from the beak. The form from the upper Morrow, which is the latest representative of the genus, is differentiated here as a new species, *E. matheri*. The form illustrated by Easton (1942, pl. VII, fig. 11) has costae coarser than those in *E. vera;* their number is the same as in *E. costata*, measuring 3.5 per 5 mm. at a distance of 20 mm., and 3 per 5 mm. at the anterior edge or 26.5 mm. from the beak. The same number of the costae can be counted on the photographs of *E. costata* in Weller, 1914, pl. LXXVI, fig. 25,27 (same photographs reproduced again in Weller, 1931, pl. XXXIX, fig. 8a,b).

Eumetria verneuiliana (Hall)
Pl. 58, fig. 1,2

1852. *Terebratula serpentaria* (?). OWEN. Geol. Rep. Wisc., Iowa and Minn.; Tab. 3A, fig. 13.

1856. *Retzia verneuiliana*. HALL, Trans. Albany Inst., vol. 4, p. 9, 1858. HALL, Iowa Geol., vol. 1, pt. 2, p. 657; pl. 23, fig. 1a–d. 1884. WALCOTT, Pal. Eureka Dist., p. 220; pl. 7, fig. 5–5a.

1882. *Eumetria verneuiliana*. WHITFIELD, Bull. Am. Mus. Nat. Hist., vol. 1, p. 50; pl. 6, fig. 28–30. 1883. HALL, 12th Rep. Ind. Geol. Survey, p. 335; pl. 29, fig. 28–30. 1894. HALL AND CLARKE, Int. to Study of Brach., pt. 2; pl. 37, fig. 1–4,6,10. 1895. HALL AND CLARKE, N. Y. Pal., vol. 8, pt. 2; pl. 51, fig. 13–26,34,35; pl. 83, fig. 26–27. 1899. GIRTY, U. S. Geol. Survey, Mon. vol. 32, p. 560; pl. 68, fig. 12a-b. 1914. WELLER, Ill. Geol. Survey, Mon. 1, p. 442–444; pl. LXXVI, fig. 18–24. 1915. SNIDER, Okla. Geol. Survey, Bull. No. 24, p. 94. 1931. WELLER, Ky. Geol. Survey, Symposium; pl. XXXVIII, fig. 7a,b. 1935. HERNON, Jour. Pal., vol. 9, p. 688–689.

1903. *Eumetria marcyi*. GIRTY, U. S. Geol. Survey, Prof. Pap. No. 16, p. 303. 1904. GIRTY, U. S. Geol. Survey, Prof. Pap. No. 21, p. 49; pl. 10, fig. 15–17. 1906. BEEDE, 30th Ann. Rep. Ind. Geol. Survey, p. 1319; pl. 22, fig. 28–30. 1911. GIRTY, U. S. Geol. Survey, Bull. 439, p. 77–79, pl. VIII, fig. 10. 1911. MORSE, Proc. Ohio State Acad. Sci., vol. 5, p. 386, fig. 14. Part 1915. GIRTY, U. S. Geol. Survey, Bull. 593, p. 75–77; pl. IV, fig. 18 (only).

The species is one of the smallest of the genus, only the new species *E. matheri* (=*E. vera*, Mather, 1915) being smaller still. Also, it has the finest costae, but not as fine as in *E. matheri*. No complete specimens have been recovered from the Redoak Hollow, and the identification is based on the general small size and spacing of the fine costae. There are counted 11 costae at the distance of 10 mm. from the beak of ventral valve, while at the same distance in the specimens illustrated by Weller (1914, pl. LXXVI, figs. 18, 19, 22, 23; also reillustrated in Weller, 1931, pl. XXXVIII, figs. 7a,b) there are about 10 costae per 5 mm. at the same distance from the beak.

EUMETRIA MATHERI, n.sp.

1915. *Eumetria vera*. MATHER, Denison Univ' Sci. Lab. Bull., vol. 18, p. 197, 198, pl. XII, fig. 14–14b.

Mather collected only three specimens of genus *Eumetria* from the upper Morrow of Arkansas, all from the Brentwood lime-

stone, the highest horizon from which the genus is known. Mather realized that the specimens are "smaller than the average among this species," but on the other hand also observed that it is like *E. vera* in shape, and has a comparable number of plications (costae): about 42. However, as one can count, the number of the costae in the middle portion of the ventral valve, at a distance 10 mm. from the beak, is 12 or 13 per 5 mm., which is a denser disposition of the costae per space and distance than in any other known species of the genus. It is also the smallest of all species, the measurements given by Mather being: length 10 mm., width 8.2 mm., and thickness 5.4 mm. These data and the high stratigraphic position seem to justify its present differentiation as a new species. It is unlike any species of the genus recovered from the Redoak Hollow and may be considered an exclusive upper Morrow form.

EUMETRIA (ACAMBONA ?) DELTOIDES
n. sp.
Pl. 58, fig. 12–14

The somewhat flattened, crushed and slightly incomplete shell resembles in outline the rare *Acambona prima* White of the Burlington (Weller, 1914, p. 449–450, pl. LXXVI, fig. 1–3), but is more nearly wedge-shaped and covered by only 32 gentle but distinct radiating plications (instead of 50 in *A. prima*) distributed between the sharply down turned postero-lateral portions of the posterior. On these narrow portions are a few additional, but hardly discernible plications. Furthermore, the shell does not possess concentric "wrinkle-like" lines of growth, which are so prominent in the type of *A. prima*. Sharply down turned and nearly flat postero-lateral segments, which make the posterior outline of the pedicle valve sharply angular, and the faintness and the number of radiating plications differentiate the new species from *A. prima* and various other species of *Eumetria* known from upper Mississippian rocks.

Discussion of brachiopods

The brachiopods comprise about one fourth of all identified species recovered from the rock specimens collected from the four fossiliferous localities of the Redoak Hollow. A few of the listed twenty-nine brachiopod species are identified or established on a combination of external and internal molds of either brachial or (very seldom) dorsal valves, but for the majority of forms both brachial and dorsal valves were reasonably established. Only a few complete brachiopod shells, composed of both valves, have been found.

Most fundamental in identification of the species or establishment of their affinities were the monograph of Mississippian brachiopods by Weller (1914), the series of comprehensive papers on the Mississippian faunas of the Midwest by Girty (1909, 1911, 1915a, 1926, 1927), and the revision of the Mississippian brachiopods by Sutton and his associates (1938, 1943). Equally valuable sources of information on American lower Pennsylvanian brachiopods were of less use in the present investigation because the brachiopods in the Redoak Hollow show less affinity with them. Before evaluating this fact for any geological conclusions, one must weigh carefully whether the known late Mississippian and early Pennsylvanian brachiopods, with which the comparison is being made at the present, are about equally representative of these two stratigraphically neighboring groups. The most important sources for understanding the lower Pennsylvanian brachiopods, the monograph by Dunbar and Condra (1932) and a series of papers by Girty (1905, 1915, 1927 and others), concern the forms that come largely from the Des Moines series, and particularly from the middle (Girty, 1915) and upper (Dunbar and Condra) parts of this series. The lower part of the Des Moines yields comparatively few invertebrates in the northern and central parts of the Mid Continent, where their material was largely collected. There is a single and important contribution on the invertebrates from the Morrow of Arkansas and Oklahoma by Mather (1915), where a number of brachiopods are described. The half-tone illustrations in this paper are not as illustrative as one would desire them to be, but in combination with the lucid text and the systematic measurements of essential dimensions for all species, their description by Mather is at a par with the contemporaneous monograph on Mississippian brachiopods by Weller (1914). Mather's data have

TABLE 5—COMPARISON OF THE CALCAREOUS BRACHIOPODS FROM THE REDOAK HOLLOW WITH THE FORMS STRATIGRAPHICALLY BELOW AND ABOVE THEM

Chester	Redoak Hollow	Morrow	Des Moines
Orthotetes kaskaskiensis Weller	*Orthotetes* [*Derbyia*] *kaskaskiensis* Weller		
Orthotetes (*-Derbyia*) *batesvillensis* Girty	*Orthotetes* (*-Derbyia*) *springerensis*, n. sp.	*O.* (*-Derbyia*) *springerensis*, n. sp.	*Derbyia crassa* Meek and Hayden
	New genus, aff. *Derbyoides* Dunbar and Condra		*Derbyoides* Dunbar & Condra
	Meekella striatocostata (Cox)	*M. striatocostata* (Cox)	*M. striatocostata* (Cox)
Chonetes chesterensis Weller	*Chonetes kingi*, n. sp.	*C. choteauensis* Mather	
Productella pyxidata (Hall)	*Productella recensis*, n. sp.		
Buxtonia semicircularis (Sutton and Wagner)	*Buxtonia semicircularis* (Sutton and Wagner)		
Buxtonia incurvatus (Sutton and Wagner)	*Buxtonia incurvatus* (Sutton and Wagner)	*Dictyoclostus morrowensis* Mather	
Buxtonia arkansana (Girty)	*Buxtonia sultoni* n. sp.		
Dictyoclostus mesialis var. *welleri*, n. var.	*Dictyoclostus mesialis* var. *springerensis*, n. var.	*D. mesialis* cf. var. *springerensis*, n. var.	
	Dictyoclostus cf. *ingrata* (Girty)	D. *ingrata* (Girty)	
	N. gen. aff. *Marginifera*	*Marginifera*	
Productus parvus Meek and Worthen	*Productus parvus* var. *matheri*, n. var.	*P. nanus* Meek and Worthen	
Productus concinnus Sowerby	*Productus stehlii* n. sp.		
Diaphragmus fasciculatus (McChesney)	*Diaphragmus fasciculatus* (McChesney)		
	D. fasciculatus var. *girtyi* n. var.		
	D. fasciculatus var. *bipilus* n. var.		
	Avonia (?) *spinosa*, n. sp.		
	Avonia (?) *snideri*, n. sp.		
Cancrinella moorefieldanus (Girty)	*Cancrinella boonensis* (Swallow)		*C. boonensis* (Swallow)
Linoproductus ovatus (Hall)	*Linoproductus ovatus* (Hall)	*L.* cf. *cora* d'Orbigny	
Spirifer cf. *opimus* Hall	*Spirifer opimus* Hall	*S. opimus* Hall	
Spirifer parvus Sutton and Wagner	*Spirifer casteri* n. sp.	*S. matheri* Dunbar & Condra	*S. rockymontanus*
Punctospirifer spinosa (Norwood and Pratten)	*Punctospirifer kentuckiensis* (Shumard)	*P. kentuckiensis* (Shumard)	*P. kentuckiensis* (Shumard)
Punctospirifer transversa (McChesney)	*Punctospirifer transversa* (McChesney)		
	Acanthospirina sp. A		
Composita rotunda Snider	*Composita rotunda* Snider	*C. ovata* Mather	*C. ovata*? Mather
Composita humilis (Girty)	*Composita wasatchensis* (White)		
Eumetria vera (Hall)	*Eumetria vera* (Hall)		
Eumetria verneuiliana (Hall)	*Eumetria verneuiliana* (Hall)	*E. matheri*, n. name	
Eumetria (*Acambona*) *prima* Weller	*E.* (*Acambona*?) *deltoides*, n. sp.		

Note: Solid lines indicate identity or close relationship of the species; dotted lines indicate their more distant relationships.

been found quite serviceable in the present comparative study of the affinities of the brachiopods from the Redoak Hollow. While the comparison of brachiopods from the Redoak Hollow with the Mississippian forms has been based largely on the descriptions and illustrations of the material from Illinois (by Stuart Weller and by Sutton), their comparison with the Morrow forms is based on those collected from the area geographically next to the Ardmore Basin. Thus the strong Mississippian affinity which the Redoak Hollow brachiopods show, is with the far away forms of Illinois (and the adjacent parts of Iowa and Missouri), while the lesser affinity is with the forms from the upper Morrow of the neighboring area of eastern Oklahoma and western Arkansas. Should we wish to compare the brachiopods of the Redoak Hollow with the brachiopods from the upper Mississippian of the nearby areas of Oklahoma, Arkansas, Texas, and Arizona (Paradise formation), we shall find that the combined information on these faunas by Girty (1911, 1915a, 1926), Snider (1915), Croneis (1930), Hernon (1935), and Easton (1942, 1943) sustains the conclusion of the strong Mississippian affinities of the forms from the Redoak Hollow, but the affinity with the forms from the upper Mississippian of Illinois is the strongest. The recently recovered well preserved invertebrate fauna from the subsurface Chester of Meade County, Kansas (material by the Stanolind Oil Co., identified by Elias), consists of the forms (brachiopods, bryozoans, pentremites, corals, ostracodes, crinoids, and others) that are identical with the corresponding forms from the Chester of Illinois, and show but little affinity with the known forms from the Pitkin and other Chester age formations of western Arkansas and eastern Oklahoma.

The available scientific information on the brachiopods from the late Mississippian and from the early Pennsylvanian marine sediments of the Midwest is of equal volume and quality.

In table 5 a list of all identified brachiopods from the Redoak Hollow is placed in the middle, flanked on either side by the two lists of identical or closely related forms: on the left the forms known in the Chester and its time equivalents, and on the right the forms known from the Morrow and contemporaneous formations. A fourth, less complete list of some forms from the Des Moines series, is added further to the right for convenience and to indicate persistence of some conservative forms high in stratigraphic sequence. A person with different or additional views on the affinity of any of the listed forms may conveniently modify the indicated relationships within the frame of this table.

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 528–570, PL. 59–62, 10 TEXT-FIG., MAY 1957

EARLY MIDDLE ORDOVICIAN OSTRACODA OF THE EASTERN UNITED STATES

PART I. STRATIGRAPHIC DATA AND DESCRIPTION OF LEPERDITIIDAE, APARCHITIDAE AND LEPERDITELLIDAE

FREDERICK M. SWAIN

ABSTRACT—Early Middle Ordovician (Chazyan) Ostracoda of the Leperditiidae, Aparchitidae, and Leperditellidae from Pennsylvania, New York, and Vermont are described and illustrated. Sixteen of the species are new. Two zones, based on Ostracoda, are recognized in the Chazyan of this region. Furthermore, the Chazyan of central and southern Pennsylvania and Virginia apparently represents a separate biofacies from that in the Lake Champlain area, New York-Vermont. The latter biofacies is comparable with that in northwestern Europe, whereas the central Appalachian biofacies resembles that of the Bromide of Oklahoma.

The lower of the two Chazy zones (*Aparchites kauffmanensis* zone) is represented in the Day Point and lower Crown Point formations of the Lake Champlain area, the Loysburg and lower Hatter formations of central Pennsylvania, and the upper Row Park and lower and middle New Market formations of southern Pennsylvania.

The upper (*Monoceratella teres*) zone of the Chazy is represented in the Crown Point formation of Lake Champlain area, the upper Hatter and lower Benner formations of central Pennsylvania, the uppermost New Market of southern Pennsylvania, and the Lincolnshire and lower Edinburg formations of Shenandoah Valley, Virginia.

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Pl. 59–62. Leperditiidae, Aparchitidae, and Leperditellidae.

INTRODUCTION

THE Ostracoda of the Chazyan Ordovician of the eastern United States have been studied only slightly, the chief contributions having been made by Ulrich (1890, 1900). Raymond (1911), Butts (1941), Kay (1944), Craig (1946), and Neuman (1951) described or listed several species from the Lake Champlain and Appalachian areas. Elsewhere Jones (1858, 1891) and Harris (1931) described ostracode species from this part of the Ordovician in Canada and Oklahoma respectively. Important recent contributions on European faunas of this general age have been made by Hessland (1949), Henningsmoen (1954), and Öpik (1938).

With the assistance of a grant from the Penrose Fund of the Geological Society of America, the writer undertook a study of Chazyan Ostracoda in 1952. A fine collection of silicified Ostracoda from the Lincolnshire and Edinburg formations near Strasburg, Virginia, loaned by the U. S. National Museum, formed the basis of the investigation. The silicified Virginia collection was studied by John C. Kraft (1957) and has provided important information on shell structure and systematics that has been applied to the mainly calicitic and less well preserved specimens from other localities. A second, but smaller, silicified collection was obtained by the writer from the Crown Point formation of Valcour Island, Lake Champlain. The type specimens are in the U. S. National Museum.

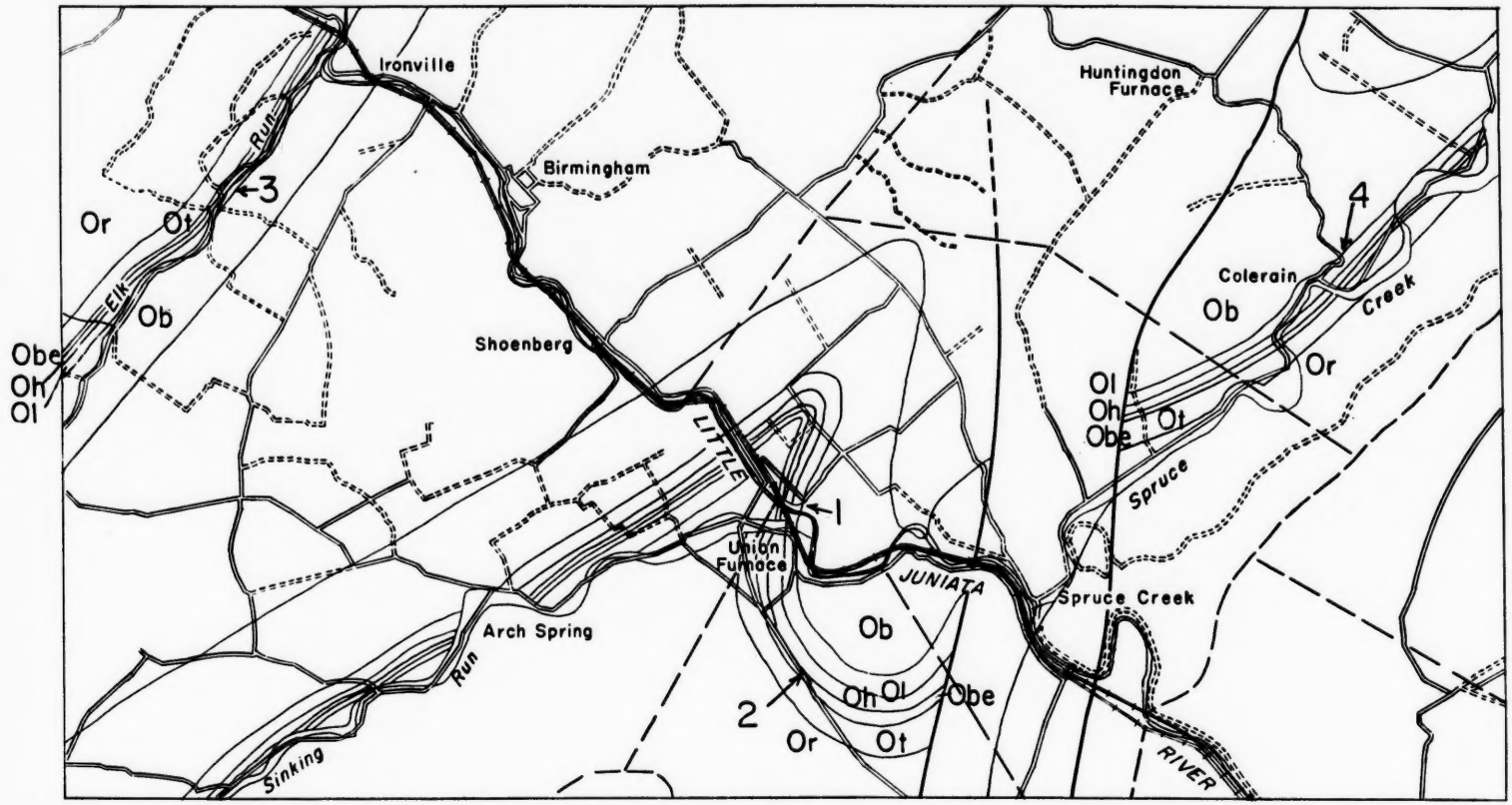
COLLECTING LOCALITIES

The collections used in this study were obtained from exposed sections or drill cores of Chazyan rocks at and near Union Furnace and Colerain, Huntingdon County, Pennsylvania; near Kauffman and Marion, Franklin County, Pennsylvania; on Valcour Island, Clinton County, New York; and on Isle La Motte, Grand Isle County, Vermont. The collecting was extended into overlying Black Riveran rocks at Chazy, Union Furnace, and Colerain.

Problems of stratigraphic nomenclature were encountered in almost every section, and while no particular emphasis has been placed on the stratigraphy, the writer has given information designed to guide later workers in locating the specific horizons from which ostracodes were obtained.

Pemberton Quarry, Union Furnace, Huntingdon County, Pennsylvania.—The Middle Ordovician sequence at Union Furnace (Text fig. *1*) has been discussed by Butts *et al.* (1939, p. 18–25), Kay (1944, p. 4), and Rones (1955). Ostracode collections were obtained from the Chazyan limestones in the eastern part of the Pemberton Quarry of the Warner Company. Measurements by means of Jacob's staff were made from top of hill along road to Eden School past east end of quarry. Poor exposures of Bellefonte dolomite (Upper Beekmantown group) occur along power line east of road.

	Bed	Total
MOHAWKIAN STAGE, lower part		
SALONA FORMATION, not sampled	92	895
NEALMONT FORMATION, not sampled	135	803
CHAZYAN STAGE		
BENNER LIMESTONE		
Stover member, not sampled	91	668
Snyder member		
Gray-brown, banded-weathering, argillaceous limestone; a medium to coarsely crystalline layer 6 inches thick, 37 feet above base has abundant small ostracodes; top not determined. Total thickness of Snyder (Kay 1944, p. 16)	97	577
White-weathering, thick-bedded limestone with tiny brecciated structure in 1-inch layers, sublithographic texture; a small fold and fault increase section about 10 feet, corrected to	40	480
HATTER LIMESTONE		
Hostler member		
Argillaceous, dark gray, very fossiliferous limestone with calcareous vein fillings, base at a bed containing large brachiopods; abundant brachiopods, bryozoans; cross-bedded 30 feet above base.	75	440



TEXT-FIG. *1*—Geologic map of Union Furnace and vicinity, Tyrone Quadrangle, Huntingdon County, Pa. (after Butts, *et al.*, 1939). Ob, Bellefonte dolomite; Ol, Loysburg limestone; Oh, Hatter limestone; Obe, Benner limestone; Ot, Trenton limestone; Or, Reedsville shale; remainder of areal geology not included. Collecting localities indicated by number: 1, Pemberton Quarry; 2, Oakland School; 3, quarry on Elk Run; 4, Colerain quarry.

	Bed	Total
Grazier and Eyer members		
Laminated, dark gray limestone with ¼ inch dark bands about 1 inch apart; frequent repetition of lithologic types represented in the previous three units.	55	365
LOYSBURG FORMATION		
Clover member		
Dark gray, white-weathering, sublithographic, wavy-laminated limestone; *Girvanella* sp. 15–17 feet above base.	20	310
Medium dark-gray, argillaceous, medium-bedded algal, partly fossiliferous limestone.	6	290
Dark gray to black, dense, partly dolomitic and laminated limestone with algal heads 5 feet above base; leperditiid ostracodes and bumastid trilobites crowded in a thin layer 29 feet above base; algal? breccia 55–57 feet above base.	70	284
Light gray- and buff-weathering, pale buff, laminated shaly-textured dolomitic limestone, becoming purer upward, a 1-foot bed of partly oolitic limestone at top; oolites both in horizontal layers and in vertical fissures.	14	214
Dark gray to medium gray, wavy-laminated magnesian limestone, with many incipient stylolite surfaces about 1 inch apart, contains first ostracodes and brachiopods.	3	200
CHAZYAN STAGE OR CANADIAN SERIES		
Transition beds with Bellefonte dolomite		
Medium to thick-bedded, dark bluish gray, dolomitic limestone, weathering light gray, in part with stylolitic and pseudo-breccia (algal?) structure, N 5° E, 46° NW.	197	197

Colerain, Huntingdon County, Pennsylvania.—A section of Middle Ordovician rocks occurs in Colerain Park and vicinity, 3 miles north of Spruce Creek. Measurements by means of Jacob's staff were made from west end of quarry on south side of road 1 mile north of entrance to Colerain Park (Text-fig. *1*); beyond quarry, measurements were made by plane table.

	Bed	Total
MAYSVILLIAN AND UPPER EDENIAN STAGES		
BALD EAGLE SANDSTONE		
Greenish-gray and mottled, ferruginous, nonporous, argillaceous, thin to thick-bedded partly cross-bedded sandstone; light brown-weathering siltstone and greenish-gray shale in beds up to 2 feet thick occur intermittently beginning 25 feet above base; a 20-foot unit of greenish-gray fissile shale with about 1 foot of sandstone in middle occurs 105–125 feet above base of unit; another 10-foot shale unit lies 180–190 feet above base; to culvert at bend in road.	250	2388
Transition beds with Bald Eagle Sandstone Interbedded fine-grained, greenish-gray to mottled, ferruginous sandstone and light brown-weathering, hackly siltstone in beds 6 inches to 1 foot thick and irregular along strike; N 75° E, 27° SE.	17	2138
Greenish gray, fine-grained, thin to thick bedded sandstone, mottled reddish brown and with scattered small shale pebbles, partly cross-laminated; partly very argillaceous and grading to sandy and silty shale along strike.	20	2121
EDENIAN STAGE		
REEDSVILLE SHALE		
Concealed, probably mainly Reedsville shale.	225	2101
Fissile, dark gray shale in laminae ⅛–¼ inch thick and interbedded 1 to 2-inch layers of very fine, limy sandstone or siltstone several feet apart; shale weathers hackly and splintery and is partly ferruginous on weathered surface; a prominent lenticular, weathered coquina 59 feet above base; weathered limestone layers with abundant crinoids, brachiopods, and bryozoa more abundant from 280 feet upward; around 290 feet are layers of greenish gray, very fine grained, argillaceous sandstone and siltstone in 2- to 6-inch layers, separated by similarly thick beds of medium gray splintery-weathering shale; partly covered in middle and upper parts. N 52° E, 33° SE, at base of exposure.	340	1876
Covered across Spruce Creek to east.	587	1536

	Bed	Total
MOHAWKIAN STAGE		
COBURN LIMESTONE		
Dark gray, thin- to medium-bedded, partly thick-bedded, finely crystalline, argillaceous limestone and dark gray slaty shale; a 5-inch bed of buff metabentonite 23 feet above base of exposure, and directly overlain by blocky calcareous shale; a highly fossiliferous layer 75–80 feet above base; remainder of exposure generally fossiliferous; to slab in culvert opposite entrance to Colerain Park.	190	949
Covered down road toward Colerain Park. At north edge of Colerain Park, N 64° E, 40° SE on huge bedding surface exposed on W side of road.	51	759
SALONA LIMESTONE		
Thin- to medium-bedded, dark gray, argillaceous limestone and interbedded dark gray slaty shale; a 4-inch bed of metabentonite 11 feet above base of exposure.	95	708
Covered. In hill above quarry, contact is exposed, traced to road as follows: N 55° W, 50 feet; N 73° W, 200 feet; N 58° W, 125 feet.	102	613
Covered along highway.	320	511
NEALMONT LIMESTONE		
Dense, dark gray, thick-bedded limestone, weathers light gray.	9	191
Covered.	13	182
Medium gray thick-bedded, somewhat argillaceous limestone.	2	169
CHAZYAN STAGE		
BENNER LIMESTONE		
Dark- to medium dark-gray, thin and crinkly bedded, argillaceous limestone with numerous highly fossiliferous layers; abundant crinoids, trilobites and other fossils beginning at 161 feet.	18	167
Medium dark-gray, thin- to medium-bedded, finely to coarsely crystalline, partly fossiliferous limestone becoming darker gray and more argillaceous above.	26	149
Medium- to dark-gray limestone, in part sublithographic, in part more crystalline in irregular areas; in part laminated due to varying crystallinity; few stylolites; N 36° E, 38° SE.	46	123
Medium- to dark-gray, medium- to thick-bedded limestone, containing light gray areas and algal structures.	19	77
Light-gray, dense, massive, sublithographic limestone, weathering pale gray slightly fossiliferous in upper part, with fossils occuring mainly in upper parts of individual beds.	11	58
Dark- to medium-gray, weathering light gray, sublithographic to finely crystalline, massive, fairly pure and fossiliferous limestone; fossils badly mascerated.	5	47
Dark gray, thick bedded to massive, partly algal argillaceous, and dolomitic limestone with a few stylolitic bands and several fossiliferous layers; several beds have, on weathered surface, rounded light gray sublithographic areas ¼–2″ across, enclosed in more coarsely crystalline and fossiliferous rock. *Nidulites*.	15	42
Dark gray, medium to thick bedded partly argillaceous limestone, weathering light gray, with many fossiliferous layers containing leperditiid ostracodes but with other fossils poorly preserved; N 33° E, 42° SE.	15	27
Medium to dark gray, in part argillaceous, thick bedded fossiliferous limestone; weathers light gray to buff with fossils appearing on weathered surface etched in relief.	12	12
Concealed below.		

Marion-Kauffman Area, Franklin County, Pennsylvania.—Classic sections of the Middle Ordovician are present in the folds south of Chambersburg, Pennsylvania. Descriptions of sections in the area have been published by Stose (1909), Craig (1942), Cooper and Cooper (1946), and Neuman (1951). Two of the localities from which ostracodes were obtained have been described in detail by Neuman (1951, p. 321, 322), to whose article the reader is referred. These are: V. Lehman farm, 1.2 miles S 65°W of Marion, and 1.6 miles N 70°W of of Kauffman, Franklin County, Pennsylvania, and 1.3 miles E of railroad station at Marion and 1 mile northeast of preceding.

The stratigraphic sequence of Chazyan rocks used by Neuman in the area is, in descending order:

CHAZYAN STAGE
ST. PAUL GROUP

New Market limestone, light- to dark-gray vaughanitic limestone with *Tetradium* above, and dark laminated cherty magnesian limestone with "*Fletcheria*" below, (460 feet).

Row Park limestone, dark-gray, cherty magnesian limestone with "*Girvanella*" and *Maclurites* and with impure vaughanite at base, gradational with underlying Beekmantown (330–545 feet).

In the summer of 1954 the writer obtained fossils from several localities south of Chambersburg. The rock sequences in these localities are shown in Text-fig. *3*. Text-fig. *2* and *4* are geologic maps of part of the Greencastle and Chambersburg 7½ minute quadrangle, modified by the writer and J. C. Kraft after Stose. The distribution of the Chazyan and adjacent rocks and the collecting localities are shown on those maps.

Valcour Island, Clinton County, New York.—The Chazyan rocks exposed on Valcour Island and the nearby mainland, Lake Champlain, were discussed by Brainerd and Seely (1888, 1891, and 1896), Cushing (1905), Raymond (1906), and Oxley (1951). The stratigraphic section on this island was given by Brainerd and Seely (1896, p. 305, 306). Three formations were recognized by Cushing in descending order, based on revised descriptions by Raymond:

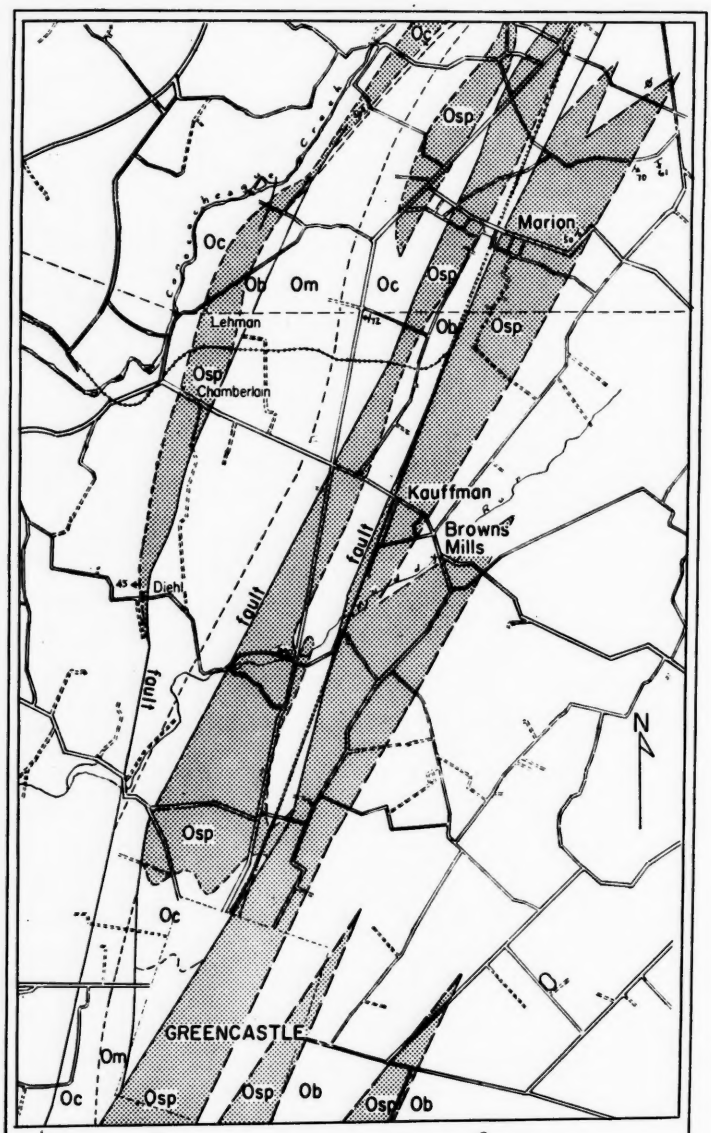
CHAZYAN STAGE	Bed	Total
Valcour limestone; dove colored, thick-bedded limestone, dark shaly limestone with *Rostricellula plena*, and arenaceous magnesian limestone and sandstone.	202	890
Crown Point limestone; dark gray, argillaceous and fossiliferous limestone with *Maclurite magnus*, and silicified fossils.	350	688
Day Point limestone; gray and bluish-gray limestone and interbedded shale with sandstone at base.	338	338

The Day Point formation is better exposed on the nearby mainland than on Valcour Island, where faulting has complicated the sections (Text-fig. *5*).

Samples containing Ostracoda, including silicified specimens were obtained from the Day Point, Crown Point, and Valcour formations on Valcour Island (Localities 1 a–c, Text-fig. *5*). The following partial section was measured beginning at the State Police Pier, near the southwestern corner of the island, at lake level. Measurements were by means of a Jacob's staff.

CHAZYAN STAGE CROWN POINT FORMATION	Bed	Total
Medium to light gray algal, dense to finely crystalline fossiliferous, medium to thick-bedded limestone with many laminae of siltstone; few bluish gray layers; N 70° W, 7° NE at Pier.	50+	138+
Dark gray, very argillaceous, dense to finely crystalline limestone, with wavy shale laminae; typically medium to thick bedded; large black silicified fossils; *Maculurites magnus* common.	15	88
Medium to light gray finely crystalline algal, oolitic, medium to thick bedded limestone.	7	73
Dark gray, very argillaceous limestone with numerous wavy shale partings; abundant brachiopods, corals, and occasional orthocerids at several horizons; a 1-foot unit containing black chert and silicified fossils 15–16 feet above base N 50° W, 15° NE at lake level, southwest corner of island.	67	67

Samples containing Ostracoda were also obtained from the southeastern part of the island in crinoidal limestones representing, according to Brainerd and Seely (1896, p. 305, 306) middle Day Point formation. Ostracode-bearing samples were also obtained from the Valcour formation in the "*Rhynchonella*" beds (*Rostricellula plena*) 30–35 feet stratigraphically below the highest exposures at the northeastern corner of the island (Locality 1 c, Fig. 5).



Om, Martinsburg shale; Oc, Chambersburg limestone; Osp, St. Paul limestone; Ob, Beekmantown dolomite and limestone. Modified after G. W. Stose 1909.

GEOLOGIC MAP OF PART OF GREENCASTLE QUADRANGLE, PENNA.

TEXT-FIG. *2*—Geologic map of part of Greencastle 7½ minute Quadrangle, Franklin County, Pa. (after Stose, 1909). Ob, Beekmantown dolomite and limestone; Osp, St. Paul limestone group, including Row Park formation below and New Market formation above; Oc, Chambersburg limestone group, including in ascending order Shippensburg, Mercersburg, and Oranda formations; Om, Martinsburg shale; complete areal geology not shown in northwestern and southwestern parts of map. Collecting localities shown by farm names.

Quarry One Mile South of Chazy, Clinton County, New York.—A section of the Black River (Lowville) limestone was measured in eastern part of quarry of Chazy Lime and Stone Company, one mile south of Chazy, New York, (Locality 3, Text-fig. 5). The beds are nearly horizontal.

	Bed	Total
MOHAWKIAN STAGE		
LOWVILLE LIMESTONE, top not exposed		
Medium to dark gray, dense to sublithographic, medium to thick bedded and partly wavy-bedded limestone with abundant gastropods, bryozoans, cystoids (?); ostracodes collected in basal layers; in other parts of quarry, layers of black dolomitic limestone containing patches of fine grained light green sandstone occur in this unit.	6+	32′ 7″+
Very dark gray argillaceous thin and wavy-bedded dense limestone with scattered nodules of black chert; partings of dark gray calcareous shale.	4′ 3″	26′ 7″
Dark gray argillaceous dense limestone weathering sooty gray, principally in a single bed and with mottled, slightly darker weathering more coarsely crystalline spots; upper surface in sharp but irregular contact with overlying layers; possibly a corrosion zone.	2′ 2″	22′ 4″
Dove gray, medium- to thick-bedded, slightly pyritic, dense to sublithographic fossiliferous limestone, occasionally with floating quartz grains; principal quarry rock used for lime manufacture; floor of quarry.	20′ 2″	20′ 2″

Isle La Motte, Grand Isle County, Vermont.—Upper Beekmantown and Chazy rocks are exposed on the southern part of Isle La Motte (Text-fig. 5, locality 2). The sequence of Upper Beekmantown and Day Point formations from which ostracodes were collected is given below (after Brainerd and Seely, 1896, p. 310):

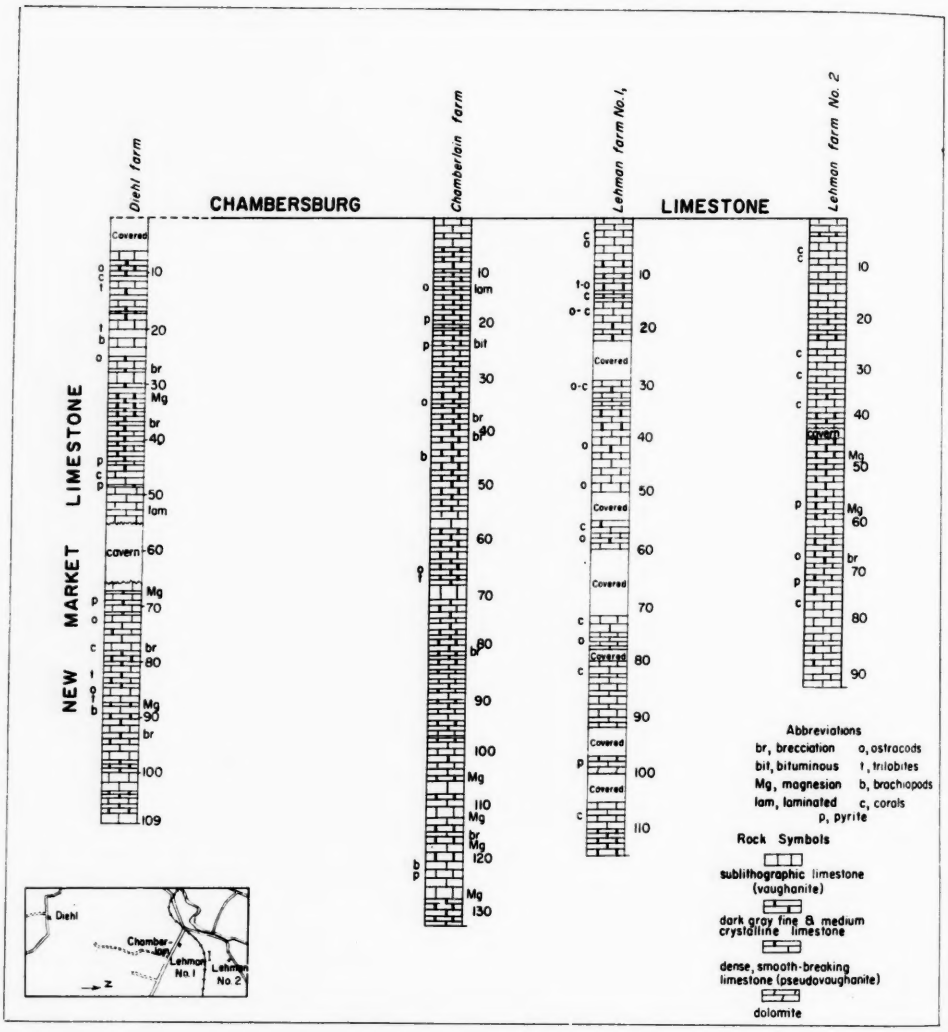
	Bed	Total
CHAZYAN STAGE		
DAY POINT FORMATION		
Crinoidal beds containing univalves and the layer of red-spotted marble; *Columnaria parva* Billings near top; Ostracoda collected in a 3-foot bed of light gray, dense, sandy limestone forming uppermost part of formation; overlying rock exposed below camp road between Fisk's Point and Fleury's Point.	70	233
Massive limestone with abundant *"Orthis" costalis* Hall.	75	163
Siliceous limestone with thin layers of slaty shale; brachiopods and trilobites.	55	88
Sandstone and slaty shale with *Lingula*.	23	23
CANADIAN SERIES		
BEEKMANTOWN GROUP (CASSIN LIMESTONE)		
Gray, coarse calcarenite with abundant echinoderm fragments, and conglomeratic limestone near lake level.	60+	60+

SUMMARY OF CHAZYAN OSTRACODE ZONES AND BIOFACIES

The problems of correlation and nomenclature in the early Middle Ordovician were discussed by Neuman (1951) and Twenhofel *et al* (1954) and need not be reviewed here. The realization in recent years that the faunal elements previously used to identify the Chazyan Stage outside the Champlain Valley (*Maclurites magnus* Lesueur, *Tetradium*, *Cryptophragmus*, etc.) are rigorously controlled by facies, has resulted in a conservative treatment of the Chazy by modern authors.

The investigation of the Chazyan Ostracoda has shown most of them to be greatly influenced by facies and with greatly variable vertical range from one species to another. A moderate number of species, however, have zonal value more or less independent of facies.

Two persistent ostracode zones have been recognized in the Chazy. The lower of the zones is characterized by frequent to common *Aparachites kauffmanensis*, n. sp., together with *A. pembertonensis*, n. sp., and is marked by the presence of many other species of which most are not restricted to the zone (Text-fig. 6–8). *A. pembertonensis* is confined to the upper part of the zone at the localities studied and has been selected to define a sub-zone of the *A. kauffmanensis*

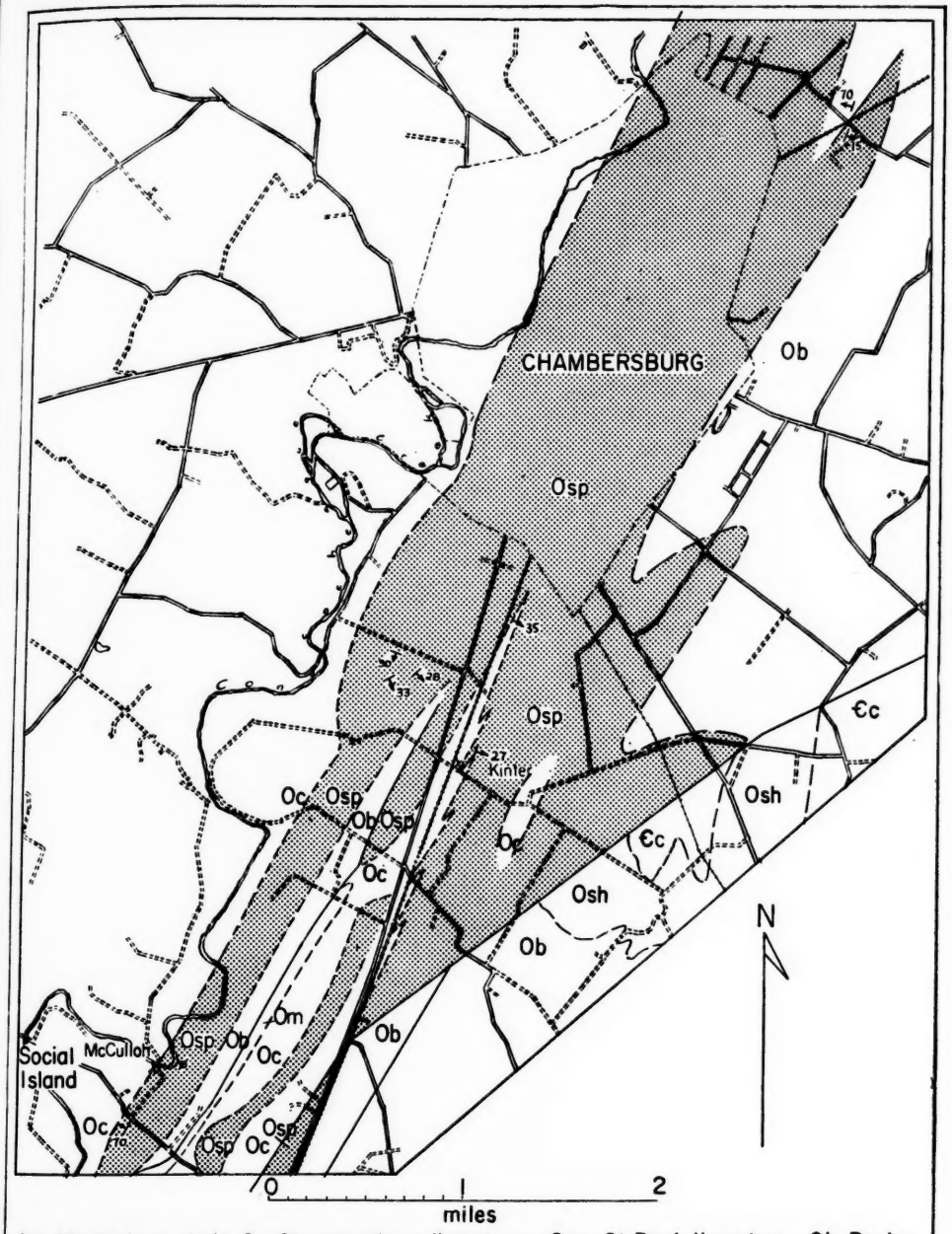


TEXT-FIG. 3—Stratigraphic sections of upper part of New Market limestone in vicinity of Marion and Kauffman, Franklin County, Pa.

zone. The base of the zone has not been adequately defined. In the Lake Champlain area the underlying Beekmantown was not thoroughly sampled for ostracodes by the writer, but on Isle La Motte, the *A. kauffmanensis* fauna was not found in the upper Cassin calcarenites. This formation contains abundant *Eurychilina* sp. and aparchitids, and *Isochilina seelyi* Whitfield was orginally described from the "Calciferous" limestone, presumably Beekmantown, on Providence Island, Lake Champlain. All these species extend into the overlying Chazy.

The base of the *A. kauffmanensis* zone apparently is in the lower Day Point limestone of New York-Vermont, the middle Loysburg of central Pennsylvania, and the upper Row Park limestone of southern Pennsylvania. The top of the zone lies in the lower part of the Crown Point, the lower Hatter and the middle New Market of New York-Vermont, central Pennsylvania, and southern Pennsylvania, respectively.

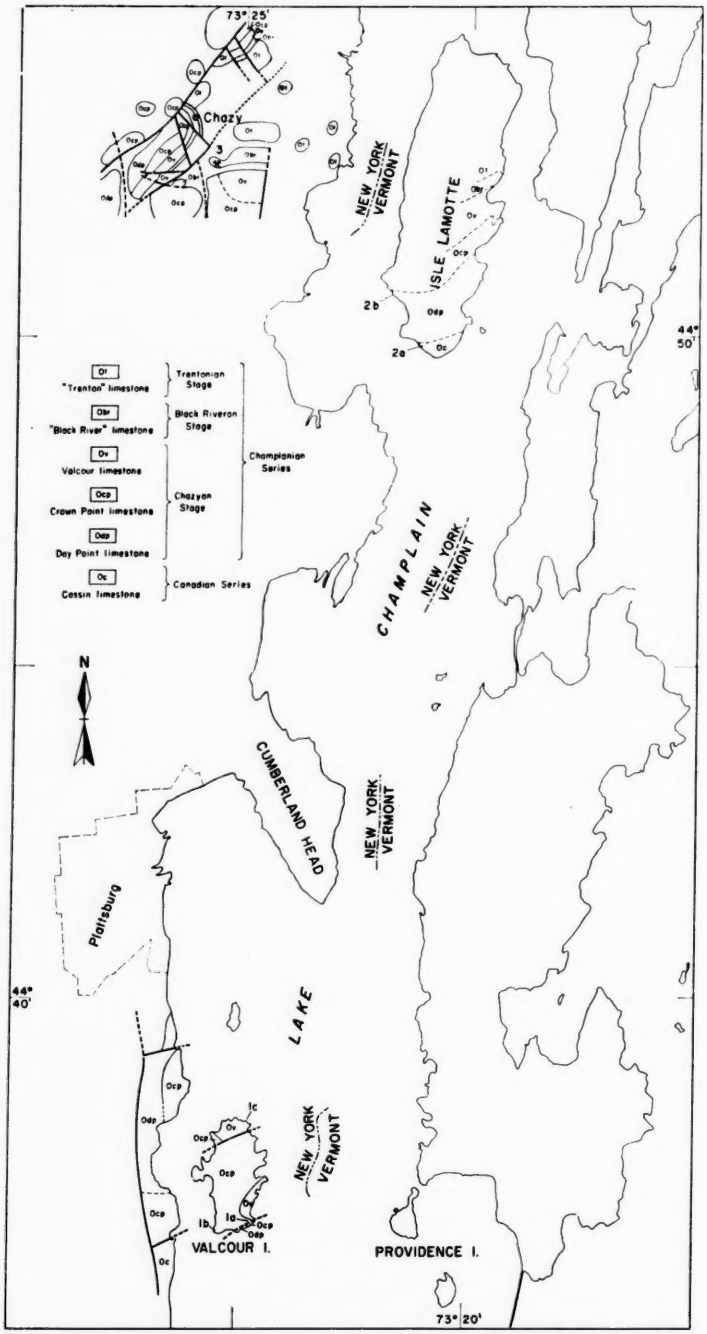
Species restricted to the *A. kauffmanensis* zone in the northern Appalachian province, in addition to that species and *A. pember-*



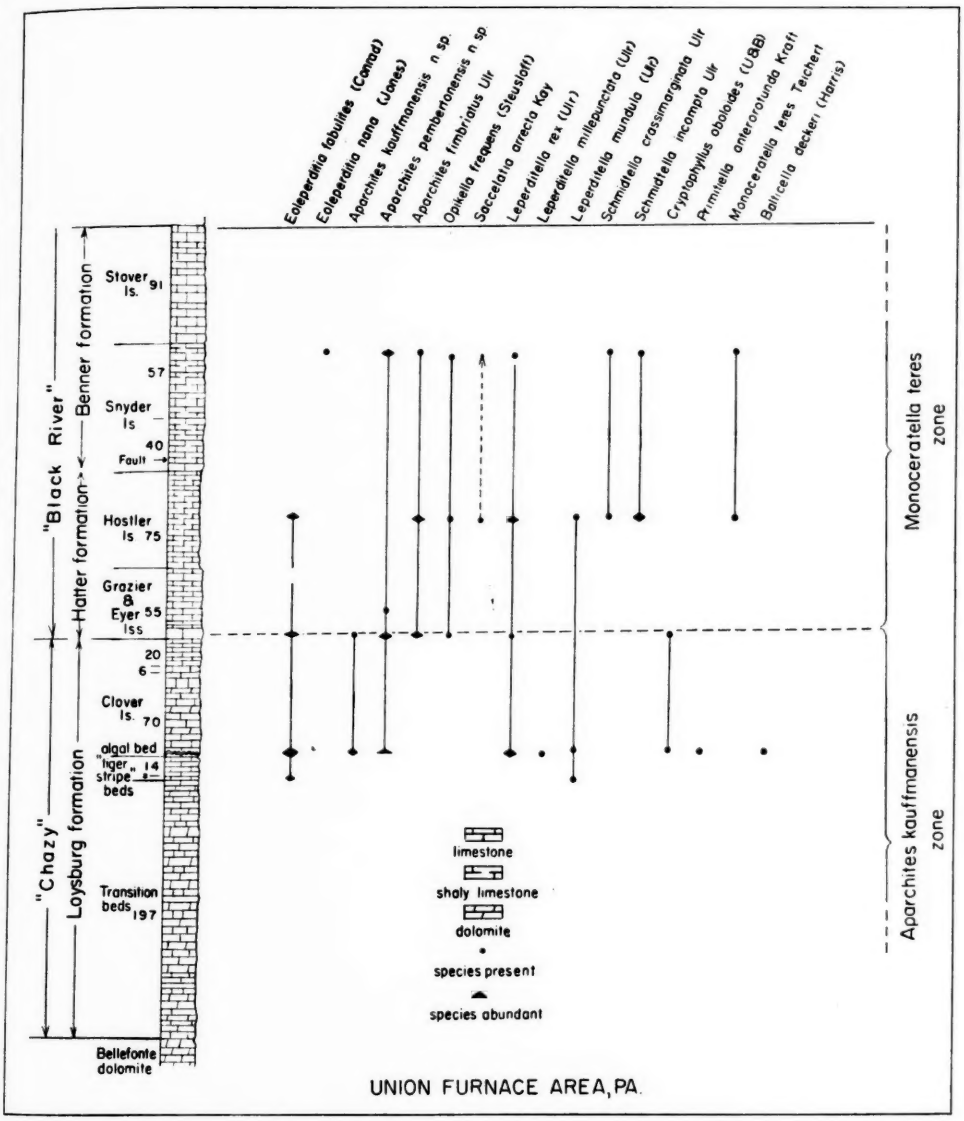
Om, Martinsburg shale; Oc, Chambersburg limestone; Osp, St. Paul limestone; Ob, Beekmantown dolomite and limestone; Osh, Stonehenge limestone; Ec, Conococheague limestone. Modified after G.W. Stose, 1909.

GEOLOGIC MAP OF PART OF CHAMBERSBURG QUADRANGLE, PENNSYLVANIA

TEXT-FIG. 4—Geologic map of part of Chambersburg 7½ minute Quadrangle (after Stose, 1909). Ec, Conococheague limestone; Osh, Stonehenge limestone; Ob, Beekmantown dolomite and limestone; Osp, St. Paul limestone; Oc, Chambersburg limestone; Om, Martinsburg shale; areal geology not completely shown in northwestern part of map. Collecting locality shown by farm name.



TEXT-FIG. 5—Geologic map of small areas in Plattsburg and Isle LaMotte Quadrangles, Clinton County, N. Y., and Grand Isle County, Vt., U. S. G. S. base (after Cushing, 1905). Collecting localities shown by numbers: 1a, Day Point formation; 1b, Crown Point formation; 1c, Valcour formation; 2a, Cassin formation; 2b, Day Point formation; 3, Lowville formation.

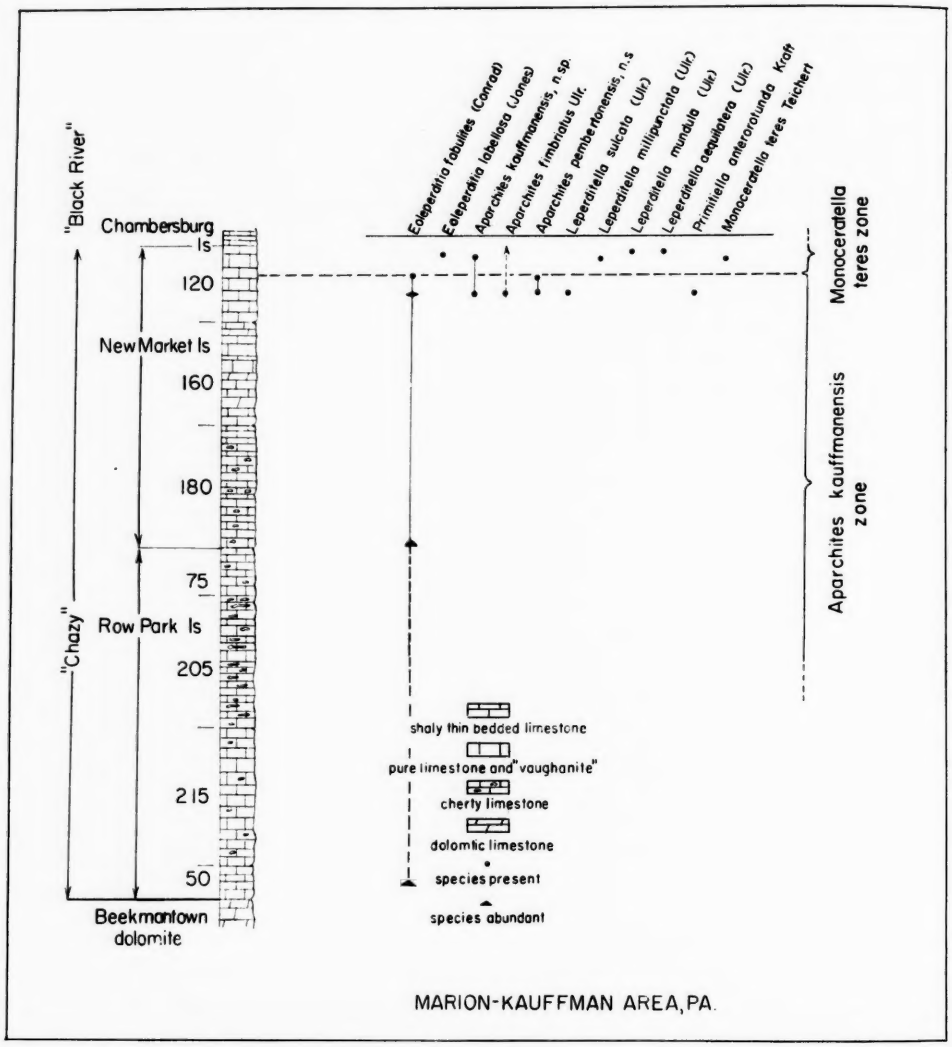


TEXT-FIG. 6—Distribution of Leperditiidae, Leperditellidae, and Aparchitidae in "Chazyan" and lower "Black Riveran" of Union Furnace area, Pa. *Monoceratella teres* Teichert and *Balticella deckeri* (Harris) are also included. It is suggested that the Hatter formation and Snyder member of the Benner formation should be included in the Chazyan on the basis of the ostracodes.

tonensis are: *Euprimitia millepunctata*, n. sp., and *Monoceratina* sp.

In the central Applachian province, the species confined to the zone are, besides *A. kauffmanensis* and *A. pembertonensis*: *Leperditia arctica* (Jones), *Leperditella sulcata* (Ulrich), *Briartina*? sp., *Öpikella*? sp., and a primitive kirkbyid.

The upper zone of the Chazyan is characterized by *Monoceratella teres* Teichert. The base of the zone is placed at the earliest occurrence of the species at a given locality. At Union Furnace, Pennsylvania *Aparchites kauffmanensis* was not found up to the base of the *M. teres* zone, but at Kauffman, Pennsylvania and on Valcour Island, New



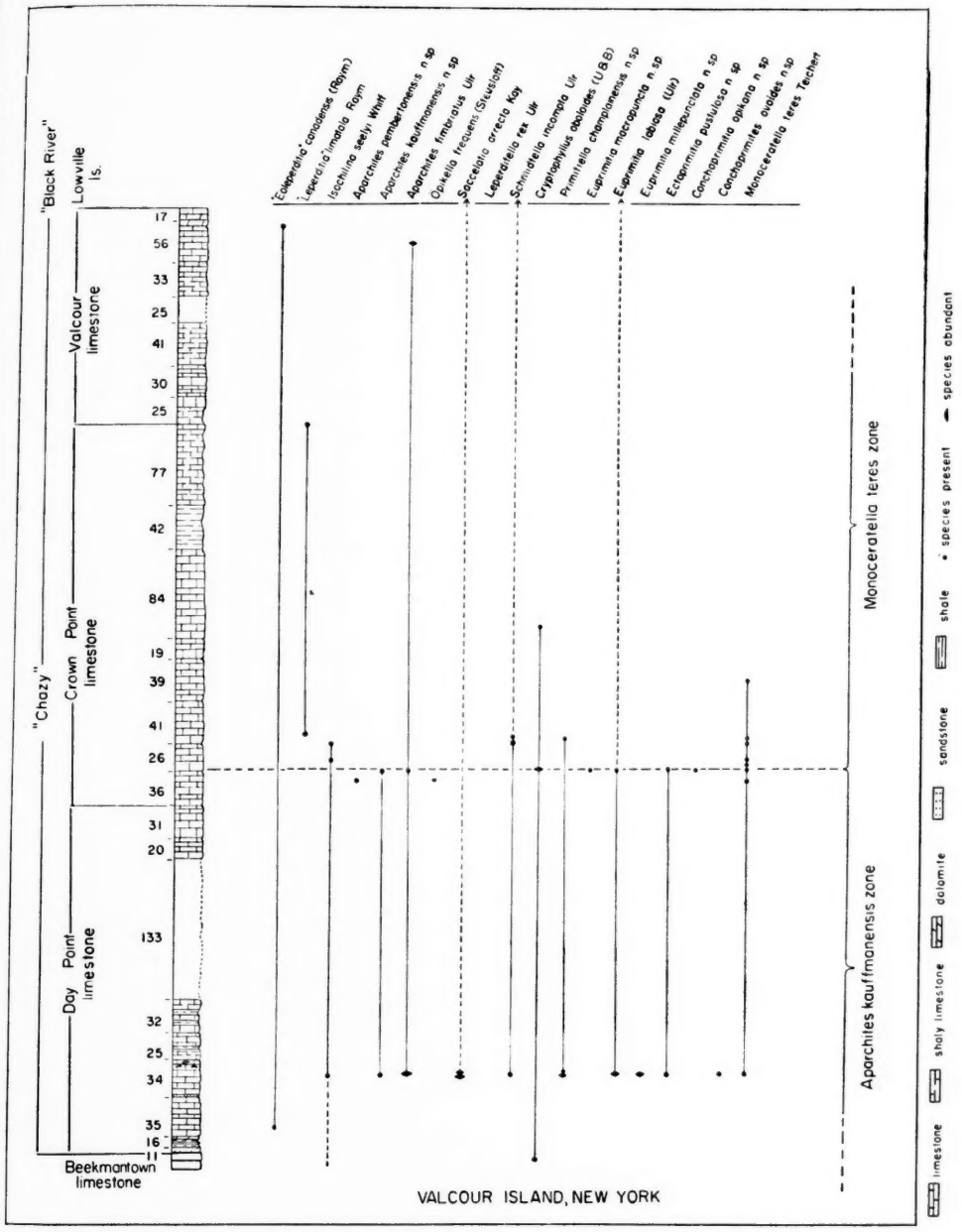
TEXT-FIG. 7—Distribution of Leperditiidae, Leperditellidae, and Aparchitidae in Chazyan of Marion-Kauffman area, Pa. *Monoceratella teres* Teichert also included.

York, *A. kauffmanensis* occurs in the basal part of the *M. teres* zone. Several species are restricted to the *M. teres* zone and occur in both provinces: *Eurychilina* n. sp. A, *E.* n. sp. B, *E.* n. sp. C, *Budnianella* n. sp., *Ctenobolbina* n. sp., and *Laccochilina* n. sp. *Isochilina limatula* (Raymond) of the Lake Champlain region and *I. signifera* Ulrich and Swain of the "lower Chambersburg" of southern Pennsylvania as closely similar species.

As shown in Text-fig. 6–8, the *M. teres* zone is represented in the Crown Point formation, the upper Hatter and lower Benner formations, the uppermost New Market, and the Lincolnshire and lower Edinburg formations in New York-Vermont, central Pennsylvania, southern Pennsylvania, and Shenandoah Valley, Virginia, respectively.

Ostracodes of the *Monoceratella teres* zone that have been found only in the northern

Appalachian province include *Primitiella* aff. *dibulbosa* Hessland, new species of *Aparchites, Tallinella, Thomasatia, Maratia, Budnianella, Alanella, Monoceratina*, a new genus, and a primitive *Sclerocypris*-like ostracode. This assemblage shows definite European affinities and may be compared with suites of ostracodes from the Ordovi-



TEXT-FIG. 8—Distribution of Leperditiidae, Leperditellidae, and Aparchitidae in Chazyan of Valcour Island, N. Y. *Monoceratella teres* Teichert also included.

cian of Sweden (Hessland, 1949), Norway (Henningsmoen, 1954), and Esthonia (Öpik, 1938).

The associated species of the *Monoceratella teres* zone in the central Appalachians have not yet been completely studied, but include the following: *Ectoprimitia* n. sp., *Bassleratia* sp., *Shenandoia?* sp., *Ctenobolbina* sp., and *Winchellatia* sp. The upper limit of the zone has not been satisfactorily determined in the East, but probably lies somewhere in the Black Riveran stage. In Minnesota, Cornell (1956) recognized three ostracode zones in the Decorah shale of late Black Riveran-early Trentonian age as follows:

3. *Bollia simplex* zone: upper part of Ion member of Decorah shale and lower part of Galena limestone.
2. *Paraschmidtella planilaterialis* zone: lower part of Ion member of Decorah shale and main part of Guttenburg member of Decorah; two subzones occur, the upper or *Conchoprimitia symmetrica* subzone (mainly Ion), and the lower or *Eurychilina reticulata* subzone (mainly Guttenburg).
1. *Eurychilina subradiata* zone: Spechts Ferry member of Decorah shale and at least upper part of Platteville limestone.

The *Monoceratella teres* zone in the East extends at least into the middle part of the Edinburg formation of Virginia, corresponding approximately to the Black Riveran-Trentonian boundary, while the *Eury-*

EXPLANATION OF PLATE 59

FIG. *1*—*Eoleperditia fabulites* (Conrad), right valve of immature specimen, lower part of Clover member of Loysburg formation, Pemberton quarries, Union Furnace, Pa., ×20.

2—*Eoleperditia nana* (Jones); a, left side of shell, lower part of Chambersburg limestone, 7 miles SW of Mercersburg Pa., ×6.3; b, exterior of a valve, broken anteroventrally, upper part of Snyder member, Benner formation, Pemberton Quarry, Union Furnace, Pa., ×20.

3—*Eoleperditia fabulites* (Conrad), right side of a shell, basal Clover member of Loysburg formation, Pemberton quarries, Union Furnace, Pa., ×4.6.

4—*Eoleperditia labellosa* (Jones), exterior of a right valve, cracked ventrally, New Market limestone, 15–20 feet below top, SW of Kauffman, Pa., ×20.

5—*Eoleperditia fabulites* (Conrad), exterior of left valve, middle Hostler member, Hatter formation, rib of quarry on Elk Run, 1½ miles S. of Ironville, Pa., ×5.3.

6—*Leperditia balthica* Jones; a, anterior view of right valve, ×1.8; b, exterior of same right valve, ×1.8; c, anterior view of complete shell, ×1.8; d, internal mold of a left valve, ×1.8; e, muscle scar and eye spot of 6b, enlarged; f, lateral view of shell of 6c; g, exterior of left valve, ×2.55; h, dorsal view of 6f; Silurian limestone, Gotland.

7—*Leperditia britannica* Rouault; a, right valve after Jones (1856), Devonian limestone, Nehou Normandy; b, transverse section from Jones after Rouault (1851) viewed from anterior so that orientation appears reversed, ×2.2.

8—*Eoleperditia fabulites* (Conrad), enlarged view of adductor muscle scar, New Market limestone, 20–24 feet below top, 2 mi. SW of Kauffman, Pa., ×10.

9—*Leperditia arctica* (Jones); a, exterior of left valve; b, exterior of right valve; c, left side of complete shell; Silurian limestone, Assistance Bay, ×10.6.

10—*Leperditia gibbera* (Jones), right valve after Jones 1856, Silurian limestone, Beechey Island, ×1.5.

11—*Briartina extenta* Ulrich and Swain, n. sp.; a, exterior of paratype left valve; b, exterior of holotype right valve; "Lowville" or "Pamelia" formation, Kingston, Ont., U.S.N.M. 108850; ×5.3.

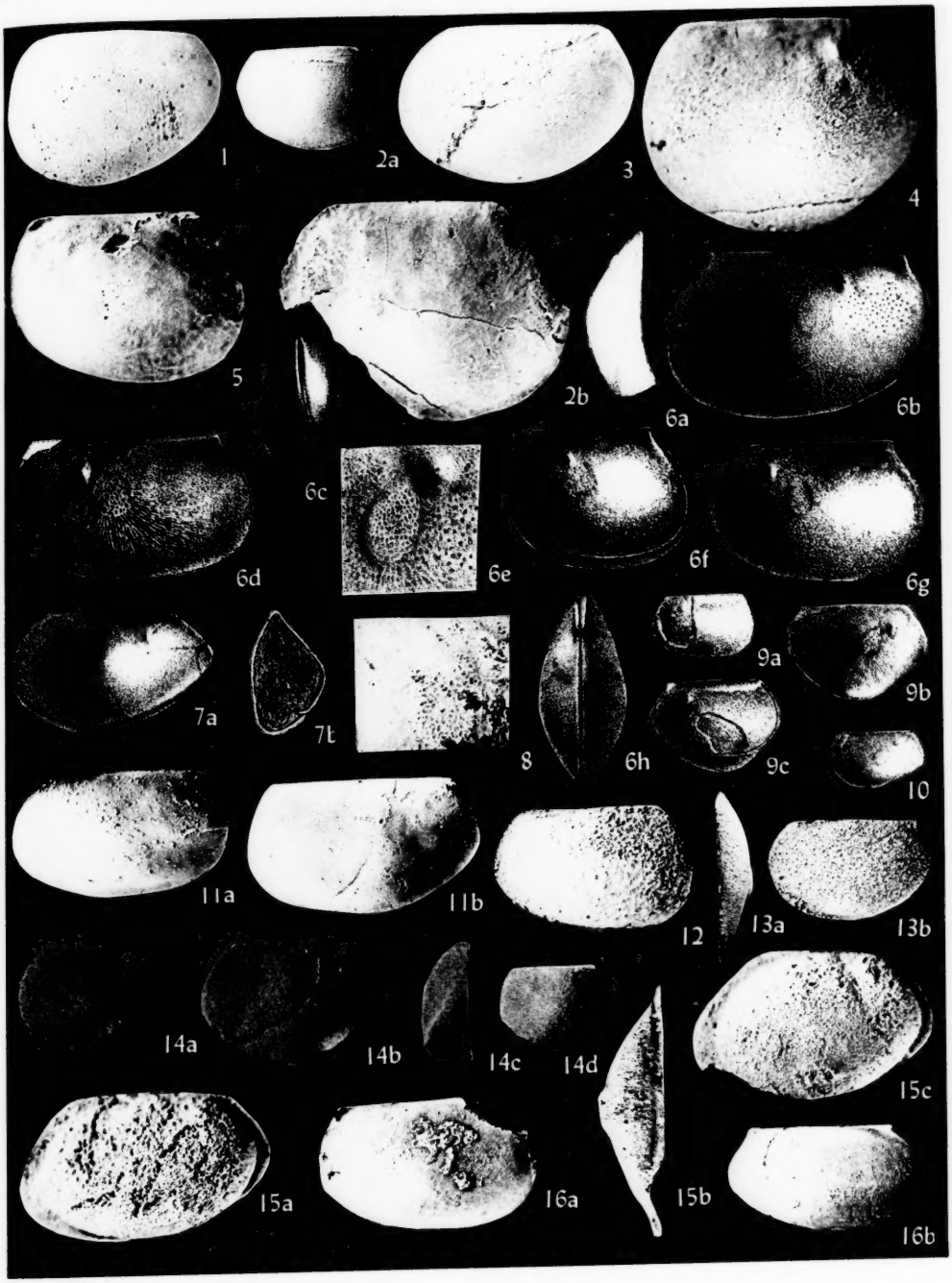
12—*Briartina modesta* Ulrich and Swain, n. sp., exterior of holotype left valve, "Ridley limestone equivalent in Highbridge or Stones River near bottom of Kentucky River Gorge at Highbridge, Ky.," ×6.2.

13—*Heterochilina kentuckyensis* (Ulrich); a, dorsal view of holotype right valve; b, lateral view of holotype; "Upper part of Tyrone limestone, High Bridge, Kentucky," U.S.N.M. 43155, ×4.9

14—*Heterochilina obligua* Poulsen; a, b, exterior views of holotype and paratype right valves, respectively; c, anterior view of holotype; d, exterior view of left valve; after Poulsen, 1937; Norwhal Sound formation, Ordovician; ×5.7.

15—*Heterochilina ventricornis* Ulrich and Swain, n. sp.; a, exterior of holotype right valve; b, ventral view of paratype, right valve; c, exterior of paratype right valve, incomplete posteroventrally; "Sandstone at base of 'Lowville' limestone, Ottawa, Canada"; ×2.3.

16—*Leperditia pergracilis* Ulrich and Swain, n. sp.; a, exterior of incomplete paraytpe left valve; b, exterior of holotype left valve cracked anteriorly; "Isochilina bed of Lower Chambersburg limestone, Blue Spring, 7 miles SW of Mercersburg, Pa."; U.S.N.M. 108851; ×3.3.


1
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5
2b
6a
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chilina subradiata zone of Minnesota begins more or less at the base of the Trentonian. Recent correlations show very little if any biostratigraphic interval between the *Monoceratella teres* zone and the *Eurychilina subradiata* zone.

LEPERDITIIDAE OTHER THAN CHAZYAN INTRODUCED FOR COMPARISON

Butts (1939, p. 20) wrote of the frequency and abundance of *Isochilina* in the Chazyan. After the present writer found few *Isochilina* in his field studies of the Chazyan he obtained Ulrich's and Ulrich and Bassler's types of *Isochilina* from the U. S. National Museum. These are described and reillustrated herein. Several of Ulrich's species to which manuscript names had been assigned are here described and illustrated under the authorship of Ulrich and Swain. Among larger Chazyan ostracodes, *Isochilina* is apparently far out numbered by species of *Eoleperditia*, at least in the northeastern U. S. The broad-flanged *Isochilina* are apparently common in the Mohawkian of parts of central and eastern U. S., together with *Leperditia* and *Heterochilina*.

In addition, three common Silurian and one Devonian species of *Leperditia* are introduced for comparison with the other Leperditiidae.

The most primitive Leperditiidae, as suggested by Swartz (1949), are those with smooth shells, such as *Eoleperditia*, without marginal flange and apparently without strong right valve overlap. These forms are common in the central and southern Appalachians and the central U. S. in Chazyan and younger Ordovician rocks. In New England, Greenland, and northwestern Europe this form was not very common in early Middle Ordovician but was more abundant later in the period. Primitive flanged, nearly equivalved Isochilininae are represented in the Canadian and Chazyan of New England by such forms as *Isochilina*

EXPLANATION OF PLATE 60

FIG. *1*—*Isochilina columbina* Bassler; a, exterior of paratype left valve, ×7; b, dorsal view of paratype left valve, ×7; c, dorsal view of paratype right valve, partly exfoliated, ×5.2; d, exterior of paratype right valve, ×6.9; e, exterior of holotype adult right valve, ×5.4; f, exterior of paratype immature right valve, ×5.4; h, exterior of paratype right valve, partly exfoliated showing impressions of adductor scar and eye spot, ×3.7; Catheys limestone, Dove member, Trentonian, Blind Asylum, Nashville, Tenn.

2—*Isochilina gregaria* (Whitfield), after Jones, 1890; exterior of two right valves, Beekmantown, Cove Island, Lake Champlain, Vt., ×14.

3—*Isochilina gregaria* (Whitfield); a, squeeze of external mold of an immature right valve, ×8.2; b, squeeze of external mold of a mature right valve, ×7.4; "Chazy, Sussex St., Ottawa, Canada."

4 a–e—*Isochilina saffordi* Ulrich; a, exterior of holotype left valve, ×2.6; b, dorsal view of holotype, ×2.1; c, ventral view of paratype right valve, ×2.8,; d, e, exterior of two imperfect right valve paratypes, ×6.5 and ×2.8; "False dove limestone of Cannon formation, Trentonian, at Nashville, Tenn.," U.S.N.M. 41288.

4 f–j, *5*—*Isochilina nelsoni* Ulrich and Bassler; 4f, external view of holotype right valve, ×2.8; 4g, dorsal view of holotype, ×2.8; 4h, ventral view of paratype right valve, ×3.0; 4i, exterior of paratype right valve, ×3.0; 4j, exterior of paratype left valve, incomplete posterodorsally, ×3.0; 5a, exterior of right valve paratype, ×3.0; 5b, dorsal view of left valve, paratype, ×3.0; "Ostracode beds of Catheys limestone, City Reservoir Hill, Nashville, Tennessee," U.S.N.M. 68765.

6—*Isochilina* sp., exterior of broken left valve, "Upper Canadian, Division E of Brainerd and Seely, Beekmantown, N. Y.," U.S.N.M. 68697, ×6.7.

7—*Isochilina mimica* Ulrich and Swain n. sp., exterior of holotype right valve, "False dove limestone of Cannon limestone, Nashville, Tenn.," U.S.N.M. 113429, ×4.7.

8—*Isochilina subnodosa* Ulrich, exterior of holotype left valve, "Trenton limestone," Perryville, Ky., ×4.3.

9—*Isochilina ampla* Ulrich; a, squeeze of internal mold of small paratype left valve, ×1.8; b, squeeze of internal mold of paratype right valve, ×1.8; "False dove limestone of Catheys limestone, Trentonian, Nashville, Tenn.," U.S.N.M. 41291.

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seelyi, but are uncommon in the central Appalachians and to the west in pre-Mohawkian times. In the Mohawkian, the large smooth *Isochilinas* developed in fair abundance in somewhat separated areas (Kentucky, Colorado), but are mostly absent in other areas (Minnesota) for no apparent ecologic reason.

The author believes that *Eoleperditia* was a basic stock from which many other American Leperditiinae and Isochilinae arose. There are several gradational species between *Isochilina* and *Leperditia*, for example, *Isochilina columbina* and *Leperditia pergracilis*, suggesting that *Isochilina* may have been ancestral to *Leperditia*, although Swartz (1949, p. 310) believed *Eoleperditia* to be the ancestor of *Leperditia*.

The subdued but striking sulcation and lobation of *Isochilina subnodosa* suggest ancestry to the large Silurian zygobeyrichiids, a group which appears to need further study.

LIST OF DESCRIBED SPECIES

The species described herein are listed below. The other Chazyan species in the writer's collection will be described later.

Leperditacea	
Leperditiidae	
(Leperditiinae)	
Eoleperditia	
EOLEPERDITIA NANA (Jones)	Chazyan-Mohawkian?
EOLEPERDITIA FABULITES (Conrad)	Chazyan-Mohawkian
EOLEPERDITIA LABELLOSA (Jones)	Chazyan
Leperditia	
LEPERDITIA PERGRACILIS Ulrich and Swain, n. sp.	L. Mohawkian?
LEPERDITIA BALTHICA (Hisinger)	(Silurian)
LEPERDITIA BRITANNICA Rouault	(Devonian)
LEPERDITIA ARCTICA Jones	(Silurian)
LEPERDITIA GIBBERA (Jones)	(Silurian)
Heterochilina	
HETEROCHILINA KENTUCKYENSIS (Ulrich)	Chazyan-L. Mohawkian
HETEROCHILINA OBLIQUA Poulsen	(Ordovician)
HETEROCHILINA VENTRICORNIS Ulrich and Swain, n. sp.	Chazyan?-L. Mohawkian
Briartina	
BRIARTINA EXTENTA Ulrich and Swain, n. sp.	Chazyan?-L. Mohawkian?
BRIARTINA MODESTA Ulrich and Swain, n. sp.	L. Mohawkian
(Isochilininae)	
Isochilina	
ISOCHILINA COLUMBINA Bassler	U. Mohawkian
ISOCHILINA GREGARIA (Whitfield)	Canadian-Chazyan
ISOCHILINA SAFFORDI Ulrich	U. Mohawkian
ISOCHILINA NELSONI Ulrich and Bassler	U. Mohawkian
ISOCHILINA SP.	Canadian
ISOCHILINA MIMICA Ulrich and Swain, n. sp.	U. Mohawkian
ISOCHILINA SUBNODOSA Ulrich	U. Mohawkian
ISOCHILINA AMPLA Ulrich	U. Mohawkian
ISOCHILINA LATIMARGINATA (Jones)	(Silurian)
ISOCHILINA LABROSA (Jones)	(Sil. Dev.)
ISOCHILINA SEELYI (Whitfield)	Canadian-Chazyan
ISOCHILINA SIGNIFERA Ulrich and Swain, n. sp.	L. Mohawkian
ISOCHILINA SP.	Chazyan
ISOCHILINA CRISTATA (Whitfield)	Canadian
Hogmochilina	
HOGMOCHILINA COLORADOENSIS Ulrich and Swain, n. sp.	U. Mohawkian
Aparchitidae	
Aparchites	
APARCHITES KAUFFMANENSIS Swain, n. sp.	Chazyan
APARCHITES PEMBERTONENSIS Swain, n. sp.	Chazyan
APARCHITES FIMBRIATUS (Ulrich)	Chazyan-Mohawkian
Öpikella	
ÖPIKELLA FREQUENS (Steusloff)	Chazyan and other Ordovician
Saccelatia	
SACCELATIA ARRECTA (Ulrich)	Chazyan-Mohawkian
Beyrichiacea	

Leperditellidae	
Leperditella	
LEPERDITELLA REX (Ulrich) Coryell and Schenk	Chazyan
LEPERDITELLA AEQUILATERA (Ulrich)	Chazyan-L. Mohawkian?
LEPERDITELLA MUNDULA (Ulrich)	Chazyan-L. Mohawkian?
LEPERDITELLA SULCATA (Ulrich)	Chazyan-L. Mohawkian?
LEPERDITELLA MILLEPUNCTATA (Ulrich)	Chazyan-Mohawkian?
Schmidtella	
SCHMIDTELLA CRASSIMARGINATA Ulrich	Canadian-Mohawkian
SCHMIDTELLA INCOMPTA Ulrich	Chazyan-Mohawkian
Cryptophyllus	
CRYPTOPHYLLUS OBOLOIDES (Ulrich and Bassler)	Canadian-Mohawkian
Primitiella	
PRIMITIELLA SP.	Chazyan
PRIMITIELLA? CHAMPLAINENSIS Swain, n. sp.	Chazyan
Euprimitia	
EUPRIMITIA SIMPLEX Swain, n. sp.	L. Chazyan
EUPRIMITIA MACROPUNCTA Swain, n. sp.	M. Chazyan
EUPRIMITIA MILLEPUNCTATA Swain, n. sp.	L. Chazyan
EUPRIMITIA LABIOSA (Ulrich)	Chazyan-Mohawkian
Ectoprimitia	
ECTOPRIMITIA PUSTULOSA Swain, n. sp.	M. Chazyan
Conchoprimitia	
CONCHOPRIMITIA ÖPIKANA Swain, n. sp.	M. Chazyan
Conchoprimites	
CONCHOPRIMITES OVOIDES Swain, n. sp.	L. Chazyan

ACKNOWLEDGMENTS

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DESCRIPTION OF SPECIES

Class OSTRACODA Latreille
Superfamily LEPERDITACEA
Family LEPERDITIIDAE Jones 1856

Large, thick-shelled Ostracoda, 5 to 20 mm. or more in length; hinge long, straight, with distinct cardinal angles; terminal margins rounded, the anterior typically the narrower; posterior margin more extended beyond end of hinge margin than is anterior margin, giving a posterior "swing" to the valves; antero-dorsally there typically is a small external tubercle representing an inner pit or thin area of shell, presumably an eye spot; medially to anteromedially is typically a large rounded adductor muscle area consisting on valve interior of numerous small, closely spaced discrete spots externally, adductor area may be represented by round swelling; venose lines ("blood canals") may radiate from muscle areas on internal and occasionally on external surfaces; general surface smooth or weakly ornamented; small markings may occur in anterodorsal region; valves equal or unequal.

Geologic range.—Upper Cambrian? to Devonian.

Subfamily LEPERDITIINAE Swartz, 1949

Inequivalved Leperditiidae, generally with right valve overlapping the left, especially in the ventral region. Flattened borders may be developed terminally, but do not continue along the ventral margin.

Geologic range.—Upper Cambrian? to Devonian.

Genus EOLEPERDITIA Swartz, 1949
EOLEPERDITIA FABULITES (Conrad)
Pl. 59, fig. 1,3,5,8

Cytherina fabulites Conrad, 1843, Acad. Nat. Sci., Phila., Proc., v. 1, p. 332.

Leperditia fabulites (Conrad), Jones, 1856, Ann. Mag. Nat. Hist., ser. 2, v. 17, p. 89; *idem.*, 1881, ser. 4, v. 8, p. 342, 1891, Contr. Can. Micro-Paleont., pt. 3, p. 98; Whitfield, 1883, Rept. Geol. Surv. Wisc., v. 1, p. 160; Ulrich, 1890, Jour. Cin. Nat. Hist., v. 13, p. 173;

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1894, Geol. and Nat. Hist. Surv. of Minn., Final Rept., v. 3, p. 634, pl. 43, fig. 10–14; Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper 1, p. 384.

Eoleperditia fabulites (Conrad), Swartz, 1949, Jour. Paleontology, v. 23, p. 318, pl. 66, fig. 1–10.

The species has been described in considerable detail by Ulrich and Swartz. As understood by Swartz (1949, p. 317) the species conforms to his concept of *Eoleperditia* in lacking a postero-dorsal swelling in the left valve. Ulrich on the other hand emphasized (1894, p. 635) that, "a low ridge-like thickening along the posterior half of the dorsal margin of the left valve is to be noticed," and he illustrated such a feature (pl. 43, fig. 11,13). Whether Ulrich's usage is valid is now uncertain, and for the present any assignments to the species of specimens from the post-Black River beds is questionable.

Occurrence.—The species was described from the Middle Ordovician on St. Joseph's Island, Canada, and the specimens used by Swartz in establishing *Eoleperditia* came from the "Lowville" limestone on that island, presumably of Black River age. Other specimens studied by Swartz and identified by him with the St. Joseph's Island examples were from the Lebanon limestone of Tennessee and the "Glade" limestone of Kentucky, both Black Riveran. The present specimens came from Union Furnace, Pa., 243½-246 feet above base of section, basal Clover member of Loysburg limestone, Chazyan; also middle Hatter formation, rim of quarry on Elk Run, 1½ mi. S. of Ironville, Pa; Upper Benner limestone, Colerain section, Pa.; Row Park and New Market limestones, near Kauffman and Marion, Pennsylvania.

EOLEPERDITIA NANA (Jones)
Pl. 59, fig. 2a,b

Leperditia canadensis Jones (part), 1858, Ann. Mag. Nat. Hist. ser. 3, v. 1, p. 244; 1891, Contr. Can. Micro-Pal., pt. 3, p. 97.

Leperditia canadensis var. *nana* Jones, 1858, Geol. Surv. Can. Ser. 5, v. 8, p. 343; 1889, ser. 6, v. 3, p. 383; Dana, 1895, Man. Geol., 4th Ed., p. 502, 503, fig. 638.

Leperditia nana Jones, 1890, Geol. Soc. London, Quart. Jour. v. 46, p. 27, pl. 4, fig. 4; Raymond, 1911, Carnegie Mus., Ann., v. 7, no. 2, p. 254; Bassler, 1915, U. S. Nat. Mus. Bull. 92. p. 704; Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper, p. 393.

Left valve subovate in side view, highest medially; dorsal margin straight with well defined obtuse cardinal angles; ventral margin moderately convex; terminal margins broadly rounded, the anterior extended medially, truncate above, the posterior slightly below. Convexity moderate, greatest medially.

Eye tubercles very small, scarcely elevated, located a considerable distance from margin. Adductor muscle area small and weakly elevated. Small compressed cardinal ears, but no marginal flange. Surface smooth.

Length of figured left valve (pl. 1, fig. 2a) 3.26 mm., height 2.26 mm.

Relationships.—The short high outline, restriction of marginal flange to cardinal ears and weak surface features distinguish this species.

Occurrence.—Figured specimen, U.S.N.M. 108852, (pl. 59, fig. 2a) labeled by Ulrich as " '*Isochilina brevis*', ostracod zone of 'lower Chambersburg' limestone, Blue Spring, 7 miles southwest of Mercersburg, Pennsylvania"; also from Pemberton Quarries, Union Furnace, Pennsylvania; middle part of Benner formation; from Canadian Series, Grenville, Quebec; Chazyan Series; Valcour Island, New York; and from Lower Ordovician (Bala) of North Wales.

EOLEPERDITIA LABELLOSA (Jones)
Pl. 59, fig. 4

Leperditia sp. nov.? Jones, 1890, Geol. Soc. Lond., Quart. Jour., v. 46, p. 553.

Isochilina labellosa Jones, 1891, Contr. Can. Micro-Paleont., pt. 3, Geol. and Nat. Hist. Surv. Can., p. 64, pl. 10, fig. 16a-c, 17,19.

Shell subovate-subhemispherical in side view, highest medially; hinge margin straight with obtuse and nearly equal cardinal angles; ventral margin strongly convex, most extended medially; anterior margin more narrowly rounded than posterior, both extended medially. Valve surface somewhat compressed, most convex anteromedially.

Eye tubercle small, lying about one-third of shell length from anterior end, and one-eighth of height from dorsum; a slightly elevated oval area posteroventerad of eye spot may represent adductor scar. Surface otherwise smooth. Cardinal areas slightly

flattened, especially anteriorly; valve edges slightly thickened.

Length of figured right valve 2.05 mm., height 1.45 mm., convexity 0.40 mm.

Remarks.—Lack of a flattened border prevents inclusion of the species in *Isochilina* as was done by Jones. The strength and median location of convexity of venter, together with smooth surface, distinguish the species.

Occurrence.—Described from the Chazyan black limestone, Broad Street, Aylmer, Quebec; also from "Birdseye" and Black River limestone in which it is associated with *Tetradium fibratum*, *Orthoceras multicameratum*, *Bathyurus*, etc. at Lot 3, Concession 3, River Front, Gloucester Township, Carelton Co., Ontario (Jones 1890, p. 69). In the present collection from New Market limestone, 15–20 feet below top, Diehl farm, 2 mi. SW of Kauffman, Pennsylvania, Upper Benner limestone, Colerain section, Pa.

Genus LEPERDITIA Rouault 1851

"Leperditiinae having a strong swelling adjacent to posterior part of hinge in left or right-plenate valve, but not in the right valve. Below the distinct eye tubercle is a chevron-like muscle mark, its detail comparable to that of the larger adductor scar" (Swartz, 1949, p. 312).

Type species.—*Leperditia britannica* Rouault.

Occurrence.—As revised by Swartz (1949) the genus was restricted in occurrence to the Middle and Upper Silurian of North America and the Silurian and Devonian of Europe. The inclusion of *L. pergracilis* Ulrich and Swain, n. sp., extends the range to Middle Ordovician of North America.

Two typical Siluran *Leperditia* are included herein for comparison.

LEPERDITIA PERGRACILIS Ulrich and Swain, n. sp.
Pl. 59, fig. 16a,b

Holotype left valve elongate subquadrate, highest about ⅝ of length from anterior end; hinge margin straight, about ⅔ of shell length, with distinct, slightly obtuse cardinal angles; ventral margin slightly convex, conconverging with dorsum toward anterior; anterior margin narrowly rounded, extended medially; posterior margin more broadly rounded extended medially, convexity moderate, greatest anteromedially.

Dorsal parts of terminal margins bear narrow only slightly compressed rims forming well defined "ears" at cardinal angles, otherwise marginal flange lacking. Small eye tubercle located slightly less than one-third from anterior end, close to dorsum; a weak furrow lies ventrad of tubercle. Adductor area very slightly elevated; covered with transluscent shell material in holotype. Surface with scattered very tiny pits. A low ridge, not extending beyond margin, occurs subparallel to dorsum in posterior half of left valve.

Length of holotype 8.63 mm., height 4.51 mm.

Relationships.—The elongate shape, restricted marginal flange, well developed cardinal ears, small eye tubercle and slightly elevated adductor area combine to distinguish this species. The posterodorsal ridge of the left valve and the weak furrow ventral to eye spot ally the species to *Leperditia.*

Occurrence.—Labeled by Ulrich "Lowville zone, *Isochilina* bed of Lower Chambersburg limestone, Blue Spring, 7 miles SW of Mercersburg, Pa., U.S.N.M. 108851."

LEPERDITIA BALTHICA (Hisinger)
Pl. 59, fig. 6a–h

Cytherina balthica Hisinger, 1831, Anteckningar I Phys. o. Geog. pt. 5, pl. 8, fig. 2; Lethaea Svecica, 1837, p. 10, 118, pl. 1, fig. 2a,b, pl. 30, fig. 1.

Cythere balthica (Hisinger), Bosquet, 1848–49, Soc. Roy. Liege, Mem. 4, p. 354.

Leperditia balthica (Hisinger), Jones, 1856, Ann. and Mag. Nat. Hist., ser. 2, v. 17, p. 85, pl. 6, fig. 1–5. (See Bassler and Kellett, 1934, p. 378,379, for more complete synonymy).

Shell subovate to subquadrate in lateral view, highest posteromedially; hinge margin straight, about two-thirds of shell length and with distinct cardinal angles; anterior cardinal angle more or less obtuse, posterior angle slightly to moderately obtuse; ventral margin moderately convex; anterior margin rounded, extended above and in some specimens with a concavity just ventrad of cardinal angle; posterior margin more broadly rounded, extended below, with pronounced concavity ventrad of cardinal angle. Valves strongly unequal; right valve

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overlapping and extending beyond (overreaching) the other along free margins. Valves not strongly convex, with greatest convexity anteromedian.

Adductor muscle scar lies anterad of middle, consisting of interior surface of a large rounded, horseshoe-shaped depression containing a reticulate pattern of small pits, and from the ventral half of which on interior surface, radiate many narrow closely spaced, branching and anastomosing canals. Anterodorsal to muscle scar lies the small pointed eye tubercle; a faint sulcus separates eye tubercle and muscle scar. A low ridge lies close to and parallel to posterior half of dorsal margin of left valve. General surface rather weakly pitted. A weak marginal border occurs on left, but is narrower or absent on right valve.

Length of a figured specimen (pl. 1, fig. 6b) 20.3 mm., height 13.8 mm.

Remarks.—This large Silurian species is figured here for comparison with other leperditiids. The strongly developed leperditiid surface ornamentation shown by this species is absent in nearly all Ordovician specimens.

Occurrence.—*L. balthica* occurs in the Middle Silurian of the island of Gotland and at other localities on the Baltic Sea and at Petschora, Russia.

LEPERDITIA BRITANNICA Rouault
Pl. 59, fig. 7a,b

Leperditia britannica Rouault, 1851, Geol. Soc. France, Bull. ser. 2, no. 8, p. 377, text-fig. 1–3. (See Bassler and Kellett, 1934, p. 381, for more complete synonymy.)

Shell sublanceolate in lateral view, highest posterior to middle; hinge margin straight, about two-thirds of length; cardinal angles distinct, broadly obtuse, the anterior slightly less than posterior; ventral margin strongly convex; anterior margin narrowly curved, subacuminate, extended above, with truncated dorsal anterior slope; posterior margin a little more broadly rounded, extended medially. Right valve larger than left, overlapping and extending strongly beyond it ventrally, less strongly terminally. Convexity of right valve low, of left valve moderate to strong, with pronounced submedian swelling; corresponding swelling in right valve more subdued and more dorsal in position.

Eye tubercle small and distinct. Valves bear narrow marginal rim ventrally and anteriorly. Ventral margin of left valve bent inward as a slight flange to receive overlapping edge of right. Left valve bears prominent posterior dorsal swelling or ridge parallel to dorsum.

Length of figured specimen 13.0 mm., height 7.4 mm.

Remarks.—The musculature of the species, and the eye tubercle, subocular V-mark, and other features characteristic of the later leperditiids have been discussed by Swartz (1949, p. 312). It is included here to show comparison with Ordovician leperditiids.

Occurrence.—The species was originally described from the Devonian of Brittany; it also occurs in Devonian limestone from Néhou, Normandy (Jones 1856, p. 90).

LEPERDITIA ARCTICA Jones
Pl. 59, fig. 9 a–c

Leperditia balthica var. *arctica* Jones, 1852, Salter's Appendix to Sutherland's Journal of a voyage in Baffin's Bay, etc., v. 2, p. 221, pl. 5, fig. 13; 1853, Quart. Jour. Geol. Soc. London, v. 9, p. 314.

Leperditia arctica (Jones), Jones, 1856, Ann. Mag. Nat. Hist., ser. 2, v. 17, p. 87, pl. 7, fig. 1–5. (See Bassler and Kellett, 1934, p. 378, for more complete synonymy.)

Shell subquadrate to subtriangular in side view, highest medially to posteromedially, dorsal margin straight, approximately four-fifths of shell length; ventral margin of right valve strongly convex, of left valve only slightly convex and subparallel to dorsum; anterior margin narrowly rounded to subangulated and extended medially in right valve, extended below in left valve; posterior margin more broadly rounded, extended medially. Right valve larger than left, overlapping and extending much beyond it ventrally, less terminally. Valves moderately convex, with greatest convexity median to ventromedian.

Eye tubercle and subocular V-mark prominent; adductor muscle scar large, oblique in an anterodorsal direction, and with radiating venose lines. Ventral surface of right valve strongly expanded in a ventral direction resulting in a pronounced overreach of left valve. Left valve with elongate swelling lying near and parallel to

dorsal margin in posterior two-thirds. General surface smooth.

Length of a figured specimen (pl. 1, fig. 9c) 17.7 mm., height 7.4 mm., convexity 5.3 mm.

Remarks.—The strong inflation of the ventral part of the right valve allies this species with *Heterochilina;* otherwise the overlap and dorsal ridge of the left valve are like *Leperditia.*

Occurrence.—Silurian limestone, Arctic America, at Cape Hotham, Assistance Bay; Seal Island, Bering Bay; Griffiths and Cornwallis Islands; Kotelny Island, Siberia.

LEPERDITIA GIBBERA (Jones)
Pl. 59, fig. 10

Leperditia gibbera Jones, 1856, Ann. Mag. Nat. Hist., Ser. 2, v. 17, p. 40, pl. 7, fig. 8–10.

Shell subtriangular in side view, highest about one-third from posterior end; dorsal margin straight, about five-sixths of shell length, with moderately obtuse cardinal angles, the anterior slightly the larger; ventral margin moderately convex, subtruncate in front; anterior margin narrowly rounded, slightly extended below, truncate above; posterior margin broadly and uniformly rounded. Shell moderately convex with strongest convexity posteroventral in position.

Adductor muscle scar slightly anteromedian, oval, oblique anterodorsally; eye tubercle small but distinct; a slight marginal rim occurs anteriorly; general surface smooth.

Length of figured right valve 8.5 mm., height 4.23 mm.

Remarks.—The ventral obesity of this species provides a resemblance to *Heterochilina,* but there are several species of *Leperditia* that also have this tendency. This species may be transitional between the two genera.

Occurrence.—Silurian limestone, Beechey Island, Lancaster Sound, Arctic America.

Genus HETEROCHILINA Poulsen, 1937

Leperditiinae with area of swelling or a narrow ridge near and subparallel to ventral margin, typically anteroventral.

Type species.—Heterochilina obliqua Poulsen.

Geologic range.—Ordovician.

HETEROCHILINA KENTUCKYENSIS (Ulrich)
Pl. 59, fig. 13a,b

Isochilina kentuckyensis Ulrich, 1891, Jour. Cincinnati Soc. Nat. Hist., v. 13, p. 179, pl. 11, fig. 11a–d.

Isochilina armata (Walcott) Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper 1, p. 337.

Right valve of holotype subovate-subquadrate in lateral view; highest slightly posterior to middle; dorsal margin straight, three-fourths of shell length with clearly defined cardinal angles, the anterior much less obtuse than the posterior; ventral margin moderately convex; anterior margin rounded extended dorsomedially, truncate above; posterior margin more broadly rounded, extended medially; valve compressed, most convex anteromedially.

Midventrally, valve surface slightly overhangs margin and there occurs a short submarginal ridge parallel to valve edge; ridge terminates abruptly behind, but grades into general valve surface anteriorly. Posterodorsally, cardinal margin of valve somewhat compressed, otherwise marginal flange absent; eye tubercle and other surface features not preserved in holotype.

Length of holotype 4.8 mm., height 2.84 mm., convexity 1.08 mm.

Relationships.—This species differs from *H. obliqua* Poulsen from the lower Ordovician of East Greenland in the shorter and more median position of the ventral marginal ridge. "*Leperditia (Isochilina)" armata* Walcott from the Birdseye and Black River limestones of Herkimer County, New York, which has a pronounced long midventral spine, probably also belongs in the genus and has been compared to *H. kentuckyensis,* but has a much longer, backward curving spine than does that species.

Occurrence.—Label in U. S. National Museum reads: "Upper part of Tyrone limestone (Lowville), High Bridge, Kentucky, U.S.N.M. 43155."

HETEROCHILINA OBLIOUA Poulsen
Pl. 59, fig, 14a–d

Heterochilina obliqua Poulsen, 1937, Medd. om. Grønland, v. 119, no. 3, p. 59–60, text-fig. 16,17.

Shell subovate in side view, highest medially to posteromedially; dorsal margin

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straight, about four-fifths of shell length, cardinal angles obtuse, the anterior the smaller; ventral margin strongly convex; terminal margins broadly rounded, the anterior extended above, the posterior extended below. Valves unequal, the right the larger. Anteroventral or midventral surface with ridge subparallel to dorsum or with ventral surface swollen to prominently overhang ventral margin.

Length of figured specimen (after Poulsen) 9 mm., height 6 mm.

Occurrence.—Ordovician, Greenland.

Heterochilina ventricornis Ulrich and Swain, n. sp.
Pl. 59, fig. 15a–c

Shell subovate in side view, highest medially to posteromedially; hinge margin straight, more than half shell length with gentle, broadly obtuse cardinal angles, ventral margin moderately to strongly convex owing to overhang of margin by ventral surface; anterior margin subacuminate, extended medially; posterior margin broader, strongly extended below, subtruncate above. Valves strongly convex for a leperditiid ostracode, greatest convexity median to anteromedian.

Small eye tubercle occurs at appreciable distance from anterodorsal margin; an oblique furrow lies posteroventrad of tubercle and extends obscurely to dorsal margin; a low swelling adjacent to furrow. Flattened marginal flange of moderate width is present terminally and extends a short distance above dorsum; ventrally flange is omitted medially by overhang of shell in holotype but not completely so in a paratype. At crest of tumid ventral surface is an elongate ridgelike swelling broken in types and of undetermined length.

A slight groove occurs along hinge surface of right valve.

Length of holotype right valve 15.2 mm., height 8.04 mm.; length of paratype right valve 15.2 mm.; height 8.63 mm., convexity 2.94 mm.

Relationships.—The shape and midventral ridge resemble the features of *H. armata* (Walcott), but the ventral tumidity of the present species is greater than that of *armata.*

Occurrence.—Labeled by Ulrich, "Sandstone at base of 'Lowville' limestone, Ottawa, Canada, U.S.N.M. 53638."

Genus Briartina Kegel, 1933

Leperditia (*Briartina*) Kegel, 1933, Preuss. Geol. Landes., Jahrb., v. 53, p. 924.

Leperditiinae with hinge margin parallel or nearly so to axis of elongation of shell; cardinal angles almost equal and shell outline quadrate, subsymmetrical. Eye tubercle located well away from anterodorsal margin.

Type species.—*Briartina quenstedti* Gumbel.

Geologic range.—Ordovician to Devonian.

Briartina extenta Ulrich and Swain, n. sp.
Pl. 59, fig. 11a,b

Shell elongate-subquadrate in side view, highest medially to slightly anteromedially; dorsal margin straight and approximately four-fifths of shell length with sharply defined not greatly obtuse cardinal angles: ventral margin gently convex; anterior margin narrowly rounded extended medially, subtruncate above; posterior margin broadly rounded slightly extended medially. Valves moderately convex, greatest convexity medial, in right valve ventral surface swollen and overhangs venter, less swollen in left valve.

A tiny inconspicuous eye tubercle lies some distance from anterodorsal corner on right valve and a slight differentiation of shell surface occurs over adductor scar posteroventral to eye tubercle. Corresponding features on left valve were not observed. General surface has tiny pits.

Length of right valve, holotype, 6.38 mm., height 3.53 mm.

Relationships.—The shape and the parallelism of dorsum to axis of greatest length ally this species with others of the genus *Briartina;* the ventral swelling of the valve surface distinguishes this from other species.

Occurrence.—Labeled by Ulrich, "Lowville or Pamelia, Kingston, Ontario." U.S.N.M. 108850.

Briartina modesta Ulrich and Swain, n. sp.
Pl. 59, fig. 12

Shell subovate-subelliptical in side view; highest about two-fifths from posterior end;

hinge margins straight with cardinal angles not sharply defined and less obtuse than typical of many other leperditiids; ventral margin gently convex, bending gradually into anterior, but abruptly into posterior margin; anterior margin rounded, extended medially; posterior margin much more broadly curved. Valve moderately convex, thickest medially. Surface smooth; eye tubercle and adductor muscle area not preserved.

Length of holotype, a left valve, 4.61 mm., height 2.74 mm.

Relationships.—The shape and parallelism of hinge and axis of greatest length of this form ally it to *Briartina* Kegel. The species is shorter and higher than *B. extenta* and lacks the ventral swelling of that species.

Occurrence.—Labeled by Ulrich, "Ridley limestone equivalent in Highbridge or Stones River near bottom of Kentucky River gorge at Highbridge Kentucky" (now under water), U.S.N.M. 54246, Black Riveran.

Subfamily ISOCHILININAE Swartz, 1949

"Leperditiinae in which the valves develop flattened borders along the ventral as well as the terminal margins and in which the closed shell appears essentially equivalved, though one valve may have a marginal flange overlapped by the other."

Geologic Range.—Ordovician to Devonian.

Genus ISOCHILINA Jones, 1858

Swartz (1949, p. 321) has brought together the published knowledge of this group and provided the following as diagnostic features:

> Free margins with flattened border; eye tubercle well-defined; other ornament typically subdued; low oval elevated area over adductor muscle scar; shallow depression may occur dorsal to adductor scar, and low inconspicuous nodes may be developed near hinge; venose lines may radiate from adductor scar. Right valve with small internal nodes along flattened border, represented externally by pits.

Type species.—*Isochilina ottawa* Jones.

Geologic range.—Ordovician to Devonian.

ISOCHILINA COLUMBINA Bassler
Pl. 60, fig. 1 a–h

Isochilina columbina Bassler, 1932, Tenn. State Geol. Surv., Cent. Basin, Tenn. p. 216, pl. 38, fig. 2.

Shell subovate-subquadrate in lateral view with pronounced swing to posterior, highest one-third from posterior end; hinge margin short for genus, about half of shell length, with broadly obtuse cardinal angles; ventral margin gently convex, converging markedly with dorsum in posterior direction in immature specimens, less so in mature shell, i.e. holotype; anterior margin rounded, extended below, subtruncate above. Valves subequal but mid-ventrally right valve extends over edge of left; convexity moderate, valves most convex anteromedially.

Terminal margins bordered by narrow compressed rims; these extend along dorsum a short distance beyond cardinal angles resulting in development of short cardinal "ears," anterior half of ventral margin bears a weak narrow rim and there are two submarginal pits medially and anteriorly along venter; these represent internal nodes. Eye tubercle small, pointed, located about one-fifth from anterior margin, but close to dorsum; ovate, slightly elevated, muscle area lies postventrad of eye tubercle; a weak node lies posterodorsad of muscle area and another weak node lies anterodorsad of eye tubercle. Surface has very tiny scattered pits.

Length of holotype, a right valve, 9.50 mm., height 5.78 mm. Length of a somewhat less elongate paratype 8.83 mm., height 5.49 mm., convexity 1.96 mm.

Relationships.—"True dove" limestone, Cannon formation, Trentonian, quarry behind Blind Asylum, Nashville, Tennessee. (U.S.N.M. 68806).

ISOCHILINA GREGARIA (Whitfield)
Pl. 60, fig. 2a,b,3a,b

Primitia gregaria Whitfield, 1889. Am. Mus. Nat. Hist., Bull. 2, p. 58, pl. 13, fig. 3–5; Lesley, 1889, Geol. Surv. Pa., Rept. P. 4, p. 743, text-fig.

Isochilina gregaria (Whitfield) Jones, 1890, Geol. Soc. London, Quart. Jour., v. 46, p. 22, pl. 1, fig. 9,10; Geol. Mag., 1903, n. s., dec. 4, v. 10, p. 304; Seely, 1910, Vt. State Geol., Rept. 7, pl. 61 fig. 16,17; Bassler, 1915, U.S. Nat. Mus., Bull. 92, p. 673; Bassler, 1919, Md. Geol. Surv., Cambrian and Ordovician vol., p. 104,163,182, pl. 36, fig. 10–12; Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper 1, p. 339.

Isochilina ottawa Jones, 1890, Geol. Soc. London, Quart. Jour. v. 46 p. 551 (Bassler and Kellett, 1934, p. 339).

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Isochilina ottawa var. *intermedia* Jones, 1891, Geol. and Nat. Hist. Surv. Canada, Contr. Can. Micro-Pal., pt. 3, p. 66, pl. 10, fig. 10a,b,11a,b; Geol. Mag. 1903, n. s., Dec. 4, v. 10, p. 103.

Isochilina amiana Ulrich, 1891, Cincinnati Soc. Nat. Hist., Jour., v. 13 p. 180, pl. 11, fig. 12a–c; Jones, 1903, Geol. Mag., n. s., dec. 4, v. 10, p. 303,304.

Shell subovate to subquadrate in side view; highest about two-fifths from posterior end; dorsal margin straight to sinuate, cardinal angles not sharply defined, the anterior much less obtuse than the posterior; ventral margin gently convex, anterior margin rounded, slightly extended above; posterior margin more broadly rounded, extended below. Valves moderately convex, greatest convexity anteromedian.

Narrow flange borders free margins except midventrally and in some specimens anteriorly where it is obscure or absent. Dorsum bears a low elevation parallel to margin which terminates anteriorly in a shallow subtriangular depression; eye tubercle small, rounded, located slightly anterad of apex of triangular depression. Surface smooth or with faint lines radiating from middle of valves.

Length of specimen figured by Ulrich (1891, p. 180) 5.1 mm., height 3.0 mm.; convexity 1.13 mm.

Relationships.—The oblique lateral outline, mid-dorsal ridge, and narrow marginal flange distinguish this species. *I. columbina* Bassler is similar in shape and narrow marginal flange but has an elevated adductor muscle area.

Occurrence.—The species was originally described from the Beekmantown, Cove Island, Balls Bay, Vermont, also from "Calciferous Sandrock," Grenville, Quebec, and from the "Chazy Limestone," Sussex Street, Ottawa and Neapau, Ontario, and from Point-Aux-Pins, Aylmer, Quebec (Jones, 1891, p. 67, Ulrich, 1891, p. 181), and from Beekmantown, Hagerstown, Maryland (Bassler, 1919, p. 104,182,363, pl. 36, fig. 10–12).

ISOCHILINA SAFFORDI Ulrich
Pl. 60, fig. 4,a–e

Isochilina saffordi Ulrich 1891, Cincinnati Soc. Nat. Hist., Jour., v. 13, p. 178, pl. 11, fig. 10a–d. Bassler, 1915, U. S. National Mus., Bull. 92, p. 674; Kirk, 1928, Am. Jour. Sci. Ser. 5, v. 16, p. 418; Bassler, 1932, Tenn. State Geol. Surv., Bull. 38, pl. 17, fig. 1.

Shell large, subquadrate to subovate in side view; hinge margin nearly straight, about four-fifths of shell length; anterior cardinal angle distinct, approximately 125 degrees; posterior cardinal angle less distinct ±157 degrees. Ventral margin moderately convex in right valve, straightened medially in left valve; anterior margin rounded, extended medially, subtruncate to weakly concave above; posterior margin broadly rounded. Valves compressed, greatest convexity two-fifths from anterior end.

Entire margin of each valve has a flange, broad terminally, relatively narrow dorsally and ventrally; at anterior cardinal angle, edge of flange forms a short spur. Midventrally, in left valve surface extended so as to nearly hide marginal flange. A small pointed eye tubercle occurs in an anterodorsal position, but well away from margin of valve. Posterior to tubercle is a narrow weak frill, immediately adjacent to which posteriorly and ventrally is the large oval low swelling, lying two-fifths from anterior end, that is the external expression of the adductor muscle area. Dorsal adductor near dorsal border is a weakly elevated small swelling. Anteroventral border of right valve bears at least one external pit which represents a cleat on inside of valve. General surface has tiny pustules.

Length of holotype, a left valve, 16.1 mm., height 9.1 mm., convexity 2.45 mm.

Relationships.—*I. saffordi* is similar to *I. ottawa* Jones, the type species, but has broader marginal flanges and larger adductor scars than the type.

Occurrence.—The holotype was described by Ulrich from the "False dove" limestone of the Cannon formation, Trentonian at Nashville, Tennessee. U.S.N.M. 412888; also from Sahara member of Perryville limestone near Harrodsburg, Kentucky, U.S.N.M. 113394, associated with *Isochilina jonesi.*

ISOCHILINA NELSONI Ulrich and Bassler
Pl. 60, fig. 4f–j, 5a,b

Isochilina nelsoni Ulrich and Bassler, 1932, Tenn. Geol. Surv., Bull. 38, pl. 21, fig. 10.

Shell large, subquadrate in lateral view; hinge margin nearly straight and two-thirds of shell length; anterior cardinal angle distinct, about 140 degrees, posterior cardinal

angle more obtuse, less distinct, also about 140 degrees; ventral margin gently convex; terminal margins broadly and nearly equally rounded, the anterior slightly the narrower, subtruncate above. Valves compressed, greatest convexity about two-fifths from anterior end.

Margins of valves bear a relatively broad flange; anterodorsally flange becomes narrow in region of eye tubercle and adductor scar; a shallow groove forms inner boundary of flange, and along outer free margins flange surface convexly rounded; anterior cardinal angle of some specimens produced as a short spur. Low pointed eye tubercle occurs anterodorsally at a considerable distance from valve margin; immediately posterojacent in a narrow, shallow groove that separates tubercle from the large oval, slightly elevated adductor muscle area. Dorsal and slightly posterior to adductor area is a small, distinct elevation that forms the anterior end of a low narrow submarginal dorsal ridge; anterior to this elevation valve surface is made irregular by two or more small depressions; a weak oblique swelling lies just beneath anterocardinal angle. Numerous tiny papillae occur on valve surfaces. Right valve bears an anteroventral submarginal pit that represents a small selvage cleat on interior surface.

Length of holotype (U.S.N.M. 68765), a right valve, 12.6 mm., height 7.15 mm., convexity 2.84 mm.

Relationships.—This species has a more strongly elevated adductor muscle area on the valve exterior than *I. saffordi* Ulrich and *I. ottawa*, Jones, and has a broader marginal flange than *I. ottawa*, species with which it is otherwise comparable.

Occurrence.—The species was described from the ostracode beds of the Catheys limestone, Trentonian, City Reservoir Hill, Nashville, Tennessee (Bassler, 1932, pl. 21, fig. 10).

ISOCHILINA sp.
Pl. 60, fig. 6

The only known specimen is an incomplete left valve having the following features: hinge straight, with sharply defined slightly obtuse cardinal angle. Anterior margin broadly rounded, distinctly concave above, extended medially. Anterior margin with compressed flange of moderate width; dorsally and ventrally, flange becomes much narrower. Eye tubercle located some distance away from anterodorsal margin and is small and rounded; bordered posteriorly by a weak furrow and behind that by the lightly elevated adductor muscle area; dorsal to adductor area is a shallow oblique furrow and beyond, near dorsal margin, are two or three small elevations; near anterodorsal angle is a low swelling with an oblique depression between it and the cardinal angle. General surface apparently smooth.

Relationships.—This Beekmantown specimen was labeled "*Isochilina praecipta*" Ulrich in the National Museum collections. Perhaps Ulrich never published the name because of incomplete data based on this single broken specimen. In shape of the anterior part of the shell it is close to *I. saffordi* Ulrich, but the muscle scar and antero-adjacent furrow are more obscure and the eye tubercle is smaller in "*praecipta.*" The species evidently represents an early differentiation of these anterodorsal features out of a leperditian ancestor.

Occurrence.—Labeled "U.S.N.M. 68697 Upper Canadian, Division E of Brainerd and Seely, Calciferous, Beekmantown, New York."

ISOCHILINA MIMICA Ulrich and Swain, n. sp.
Pl. 60, fig. 7

Holotype a subquadrate right valve, highest medially, as viewed laterally; hinge margin nearly straight, about two-thirds of shell length; cardinal angles, well defined, obtuse, the anterior 135 degrees, the posterior 134 degrees; ventral margin moderately convex, subtruncate in anteroventral region; anterior margin rather narrowly rounded for the genus, strongly extended medially, subtruncate above; posterior margin broadly rounded, extended below. Valve compressed, most convex anteromedially.

Terminal margins compressed to form rather broad flanges; this feature continues around part of ventral margin, but is very narrow or absent anteromidventrally; posterodorsally, flange continues for a short distance along dorsum; anterodorsally, flange stops just behind cardinal angle. Eye tubercle lies nearly one-fourth of shell length from anterior end, but very close to dorsum, and is defined fore and aft by short,

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shallow furrows. Adductor muscle scar represented on exterior by large, slightly elevated, oval area posteroventrad of eye tubercle. In anteroventral part of valve a low ridgelike swelling parallels margin; mid- and posteroventrally a broad swelling lies parallel to margin. Dorsad of this swelling, posterior shell surface depressed. General surface of valve bears extremely small pustules. A small submarginal pit occurs posteroventrally, and apparently represents a selvage cleat on interior surface.

Length of holotype, a right valve, 6.86 mm., height 4.02 mm.

Relationships.—This species is related in general shape, eye spot, muscle area, and marginal flanges to *I. saffordi* Ulrich and, in its development of an incipient posterior ventral lobe, to *I. subnodosa*. If the posteroventral swelling of *I. mimica* were to be extended to the dorsal region a close similarity to *I. subnodosa* would be attained.

Occurrence.—The holotype is from the "False Dove" limestone of the Cannon limestone, Trentonian, Nashville, Tennessee, along Central Tennessee Railroad, U.S.N.M. 113429, collected by Ulrich.

ISOCHILINA SUBNODOSA Ulrich
Pl. 60, fig. 8

Isochilina subnodosa Ulrich, 1890, Jour. Cincinnati Soc. Nat. Hist., v. 13, p. 177, pl. 11, fig. 7a–c.

Left valve (holotype) subrectangular in side view; hinge margin nearly straight, and two-thirds of shell length; cardinal angles obtuse, the anterior about 145°, the posterior about 130°; ventral margin moderately convex; terminal margins broadly rounded, extended medially. Valve compressed, with greatest convexity anteromedian.

Anterodorsally, but well within valve margin (one-fourth of length from anterior end and one-seventh of height from dorsum) is a low, small eye tubercle, defined posteriorly by a short oblique furrow on the flank of a large rounded antero-median lobe, which represents the external expression of the adductor muscle scar; this lobe has a shallow though fairly well defined median sulcus bordering it posteriorly; middorsally and close to margin is a small elevation separated from adductor scar by a faint furrow and bordered behind by median sulcus. Posterior to middle, shell surface formed into a curving posterior lobe. Posterior one-fifth of shell compressed; ventrally compressed border of shell much narrower, with a shallow groove on its inner side; anteriorly compressed flange of moderate width, also with inner groove. General surface possesses very tiny, widely spaced pustules which, when worn off, appear as pits.

Length of holotype, a left valve, 7.94 mm., height 4.51 mm.

Relationships.—The median sulcus distinguishes this species from other *Isochilina*, and at the same time provides a relationship to certain later Ordovician and Silurian large Beyrichiacea, such as *Zygobeyrichia*.

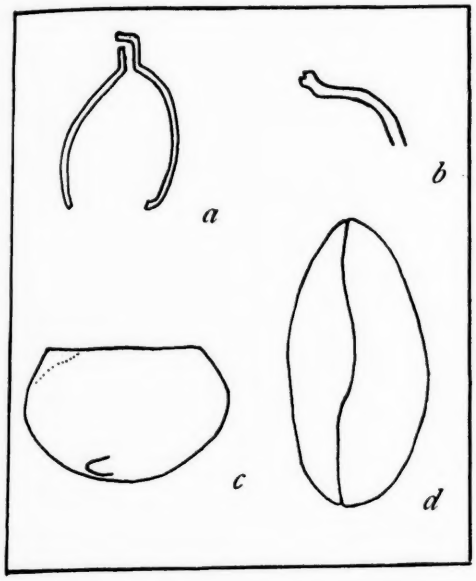
Occurrence.—The holotype is from the Trenton limestone at Perryville, Kentucky; also on same slab with holotype of *Isochilina coloradensis* Ulrich, Harding sandstone, near Cañon City, Colorado.

ISOCHILINA AMPLA Ulrich
Pl. 60, fig. 9a,b; Pl. 61, fig. 1

Isochilina ampla Ulrich, 1891, Jour. Cinn. Soc. Nat. Hist., v. 13, p. 179, pl. 11, fig. 8–ad, Bassler, 1915, U.S. Nat. Mus., Bull. 92, p. 672; 1932, Tenn. State Geol. Surv., Bull. 38, p. 17, fig. 3.

Shell large, subovate in side view; hinge margin nearly straight, about two-thirds of shell length; anterior cardinal angle not clearly defined, about 145°; posterior cardinal angle better defined, about 130°; ventral margin strongly convex; converging toward dorsum in anterior direction; anterior margin rounded, extended above; posterior margin more broadly rounded, extended below. Valves moderately convex for the genus, greatest convexity anteromedian.

Dorsal and terminal margins compressed to form a marginal flange. Wall structure consists of prismatic calcite as seen in a broken specimen. Hingement formed by contact of dorsal flanges, that of right valve bearing a slight crimp (Text-fig. 9a) for reception of dorsal edge of left. Eye tubercle small, pointed, located about one-fifth of shell length from anterior end but very close to dorsum; adductor muscle area large, not strongly elevated on exterior; a slight furrow separates muscle scar from eye tubercle; about 12 small irregular, partly



TEXT-FIG. 9—SKETCHES OF LEPERDITIIDAE

a, *Isochilina ampla* Ulrich, reconstruction of hinge-margin relationships based on the type specimens, Catheys limestone (Trentonian), Nashville Tennessee.

b, *Heterochilina ventricornis* (Ulrich), cross section of hinge area of holotype right valve, Sandstone at base of 'Lowville' limestone, Ottawa, Canada.

c, *Heterochilina kentuckyensis* (Ulrich), exterior of holotype right valve showing pointed ventral ala and posterodorsal flattening, upper part of Tyrone limestone, High Bridge, Kentucky.

d, *Isochilina columbina* Bassler, ventral view of a paratype shell, showing mid-ventral overlap by right valve, Cathey's limestone, Trentonian, Nashville, Tenn.

anastomosing ridges radiate ventrally and posteriorly from scar. General exterior surface smooth.

Length of holotype, an internal mold of a right valve, 21.0 mm., height 16.5 mm.

Relationships.—The size, great height with respect to length, and subdued exterior surface ornamentation distinguish this species. Ulrich (1891, p. 179) observed that it is relatively similar to *I. jonesi* (Weatherby), the latter has stronger anterodorsal ornamentations and is more elongate. Kirk (1928, p. 411) considered the species to belong with *Leperditia* because of the right valve overlap, and perhaps also because of the presence of a papilla at each end of the ventral selvage ridge of right valve, represented by small, submarginal exterior pits. Kirk considered *I. ampla* to resemble *Leperditia appressa* Ulrich, but it is larger and more tumid than that species and, in comparison to *L. tumidula* Ulrich, lacks strong ventral tumidity.

ISOCHILINA LATIMARGINATA (Jones)
Pl. 61, fig. 4a,b

Leperditia marginata Jones (not Keyserling), 1856, Ann. Mag. Nat. Hist., Ser. 2, v. 17, p. 91, pl. 7, fig. 14a–d.

Isochilina grandis Jones (1881) (not Schrenk), Ann. Mag. Nat. Hist., Ser. 5, v. 8, p. 347, etc. (See Bassler and Kellett, 1934, p. 340)

Isochilina grandis var. *latimarginata* Jones, 1891, Cont. Can. Micro-Paleont., pt. 3, p. 78, pl. 10, fig. 1–4.

Isochilina latimarginata (Jones), Bassler and Kellett, 1934, p. 340.

Isochilina phaseolus marginata Schmidt 1883, Acad. Imp. Sci. St. Petersburg, Mem., ser. 7, v. 31, p. 5, etc. (See Bassler and Kellett, 1934, p. 340.)

This species was described thoroughly by Jones (1891, p. 78,79). It is characterized by flattened free-marginal rim of moderate width, bisulcate anterodorsal area, with the adductor muscle area forming the "median lobe."

Length of figured left valve approximately 20 mm., height approximately 13 mm.

Remarks.—The surface ornamentation of this species suggests that it is transitional to some of the sulcate larger Beyrichiacea. It is similar to *Isochilina subnodosa* but the sulcation extends less far ventrally than in that species.

Occurrence.—"Silurian limestone . . . Pine Island Lake on the English or Great River, a few miles north of Cumberland House" (Jones 1856, p. 94); Middle Silurian, Lake Winnepegosis and Cedar Lake and vicinity, Manitoba.

ISOCHILINA LABROSA (Jones)
Pl. 61, fig. 5a,b

Leperditia canadensis var. labrosa Jones, 1858, Ann. and Mag. Nat. Hist., Ser. 3, v. 1, p. 245, pl. 9, fig. 13a,b.

Leperditia labrosa Jones, 1891, Contr. Can. Micro-Paleont. pt. 3, p. 97

Shall subquadrate in lateral view, highest medially; hinge margin straight, about five-sixths of shell length; anterior cardinal angle only slightly obtuse, posterior cardinal angle more obtuse; ventral margin not strongly convex, straightened medially;

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terminal margins broadly rounded; the posterior slightly extended below. Valves compressed, most convex anterior to and slightly ventrad of middle.

Adductor muscle area raised as a small lobe in an anterodorsal position; with short sulcus on either flank; eye tubercle inconspicuous; free margin with flattened border of moderate width.

Length of Jones' figured left valve 4.2 mm., height 2.5 mm.

Remarks.—The weak sulcation and marginal rim relate this species to the group of *I. nelsoni* and *I. subnodosa*.

Occurrence.—Lower Devonian, Helderbergian of Cape Bon Ami, New Brunswick; Yeringian, Cave Hill, Lilydale, Victoria.

ISOCHILINA SEELYI (Whitfield)
Pl. 61, fig. 6,7a–d

Primitia seelyi Whitfield, 1889, Am. Mus. Nat. Hist., Bull. 11, p. 60, pl. 13, fig. 6,7; Lesley, 1889, Geol. Survey Pa., Soc. Rept. p. 774, 2 text-fig.

Isochilina seelyi (Whitfield), Jones 1890, Geol. Soc. London, Quart. Jour., v. 46, p. 22, pl. 1, fig. 7; Seely, 1910, Vt. State Geol., Rept. 7, pl. 61, fig. 17; Bassler, 1915, U.S. Nat. Mus., Bull. 92, p. 674; Md. Geol. Surv., Camb. and Ordo. vol., p. 105, 182, 363, pl. 35. fig. 12; Kirk, 1928, Am. Jour. Sci., ser. 5 vol. 16, p. 416; Bassler and Kellett, 1934, Geol. Soc. Am. Spec. Paper 1, p. 342.

Shell subquadrate-subovate in lateral view, highest about two-fifths from posterior end; dorsal margin straight, with well defined cardinal angles, the anterior much less obtuse than the posterior, and typically slightly projected earlike; ventral margin moderately convex, more so in right than in left valve; anterior margin rounded, extended medially to ventro-medially, concave above because of cardinal ear; posterior margin broadly rounded, extended medially to somewhat ventromedially, subtruncate above. Valves moderately convex posteromedian and slightly ventral to midheight. Valves nearly equal, but free edge of left valve slopes abruptly toward interior, and is slightly overlapped by projecting edge of right.

Free terminal marginal border of each valve compressed as a broad rim; midventrally rim disappears. Eye tubercle lies one-third valve length from anterior margin and one-fourth of height from dorsal margin, thus is considerably more removed from margin than is typical of genus. A large oval, oblique, smooth, slightly elevated, adductor muscle scar lies posteroventral of eye tubercle. In some specimens, particularly immature molts, a slight furrow lies anterad of eye spot and in a few a posterior furrow occurs. Both right and left valves may show low ridge-like swellings parallel to dorsum in posterior half of shell. General surface coarsely pitted, width of interspaces averaging slightly more than diameter of pits; marginal rims, dorsal border, muscle scar, and antero-cardinal area of shell smooth.

Dimorphism may occur in this species; some valves are relatively more elongate and less convex on the ventral margin and in the ventral valve surface (pl. 61, fig. 7b); these may be male specimens.

Length of a figured higher dimorph (pl. 61, fig. 7d) 5.0 mm., height 3.1 mm., convexity 1.1 mm.; length of an elongate right valve 5.1 mm., height 2.9 mm., convexity 1.2 mm.

Remarks.—The present specimens are topotypes from Providence Island, Vermont, Jones (1890, p. 22). Specimens from that place were said to lack the anterodorsal smooth area which occurs in this collection and which Whitfield also noted. The posteroventral position of greatest convexity is much different from that in *I. saffordi* and other large Trenton species. The dimorphism is perhaps also unique, although specimens of *Isochilina* are generally so isolated that comparative studies of such features as dimorphism are difficult.

Occurrence.—"Birdseye limestone," possibly Chazyan in age, Providence Island, Lake Champlain, Vermont and from Shoreham, Vermont. Specimens in the collections of the University of Minnesota are labeled "Calciferous (Beekmantown) limestone, Providence Island." Also obtained from Crown Point formation, 50–65 feet above base, and Day Point formation 75–80 feet above base, Valcour Island, New York.

ISOCHILINA SIGNIFERA Ulrich and Swain, n. sp.
Pl. 61, fig. 8a,b

Shell subovate in lateral view, highest medially to posteromedially; dorsal margin straight to sinuous, about four-fifths of shell

length, anterior cardinal angle a little more obtuse than posterior; ventral margin moderately to strongly convex, converging slightly with dorsum in an anterior direction; anterior margin rounded, extended medially to ventromedially and truncate to concave above; posterior margin more broadly rounded, slightly extended below. Valves not strongly convex, greatest convexity median to anteromedian; anteroventrally, surface slightly overhangs margin.

Eye tubercle distinct, but not strongly elevated; adductor muscle area oblique anterodorsally and with many radiating, branching, and anastomosing weak ridges that extend nearly to venter but posteriorly are broken up into small irregular pustules. Posteroventrally a large, rounded, elevated area is broken over its surface in both left valves at hand. Terminal and posteroventral marginal areas with flattened, rather narrow border.

Length of holotype, a left valve, 3.16 mm., height 2.10 mm.

Relationships.—In shape, flattened marginal areas, and venose surface ornamentation this species is closely similar to *Leperditia limatula* (Raymond) from the Crown Point formation on Valcour Island, New York. That species, however, is said to have the right valve considerably overlapping the left, and to have pits along the anterior and posterior marginal flanges which were not observed in the present species.

Occurrence.—Labeled by Ulrich "Lower Chambersburg limestone, ostracode zone, Blue Springs, 7 miles southwest of Mercersburg, Pennsylvania, U.S.N.M. 68776.

ISOCHILINA CRISTATA (Whitfield)
Pl. 61, fig. 10

Primitia? cristata Whitfield, 1889, Am. Mus. Nat. Hist., Bull., v. 2, no. 2, p. 59, pl. 13, fig. 1,2; Lesley, 1889, Geol. Surv. Pa., Rept. p. 4, p. 743.

Isochilina cristata (Whitfield), Jones 1890, Quart. Jour. Geol. Soc., London, v. 46, p. 23, pl. 1, fig. 8; 1903, Geol. Mag. n. s., dec. 4, v. 10, p. 304; Seely, 1910, Vt. Geol. Surv. Rept. 7, pl. 61 fig. 15; Bassler, 1915, U. S. Nat. Mus., Bull. 92, p. 672.

Isochilina amiana insignis Ulrich, 1891, Cinn. Soc. Nat. Hist., Jour., v. 13, pt. 1, p. 181, pl. 11, fig. 13.

Shell subrhomboidal in side view; dorsal margin straight, approximatelythree-fourths of shell length, cardinal angles obtuse, the posterior the larger; ventral margin moderately convex; anterior margin rounded, pronouncedly extended above, and with slight concavity near cardinal angle; posterior margin rounded, strongly extended below. Valves subequal, convexity low.

V-shaped sulcus lies anterad of midlength and extends to dorsal margin, narrowing near midheight; an oblique ridge lies posteroventral to base of sulcus; free margins with narrow rim; general surface smooth.

Length of figured right valve 2.8 mm., height 1.8 mm.

Relationships.—This species is closely similar to *Isochilina gregaria* (Whitfield) in shape and character of median sulcus, but that species lacks the oblique midventral ridge.

Occurrence.—Lower Ordovician, Beekmantown, hard black calcareous shale, Cove Island, Ball's Bay, Lake Champlain, Vermont.

Genus HOGMOCHILINA Solle, 1935

Isochilininae with furrow behind eye tubercle essentially perpendicular to hinge, rather than in line above adductor as in *Isochilina;* submarginal pits and corresponding internal nodes lacking.

Type species.—*Isochilina* (*Hogmochilina*) *elliptica* Solle.

Geologic range.—Ordovician to Devonian.

HOGMOCHILINA COLORADOENSIS Ulrich and Swain, n. sp.
Pl. 61, fig. 2,3a,b

Shell subovate in lateral view, highest about one-third from posterior end; dorsal margin straight with obtuse cardinal angles, the anterior more distinct and less obtuse than the posterior; ventral margin moderately convex rising obliquely toward dorsum in an anterior direction; anterior margin rounded, extended dorso-medially, subtruncated above; posterior margin much more broadly rounded, extended medially to ventromedially. Valves compressed, most convex anteriorly. Ventrally, valve surface overhangs margin.

Terminal margins and terminal parts of dorsal margin bear narrow flattened rim; midventrally, rim absent. Small eye tubercle occurs anterodorsally, but at some distance

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from margin; a shallow broad furrow defines tubercle posteroventrally and beyond is a low obscure swelling which represents adductor muscle scar. Surfaces of type specimens, preserved in sandstone, otherwise have no ornamentation.

Length of holotype, a right valve, 14.2 mm., height 7.65 mm.; length of paratype, a left valve, 11.3 mm., height 6.57 mm., convexity 2.65 mm.

Realtionships.—The narrow marginal flange, general shape and post-ocular furrow of this species furnish a comparison with *Isochilina ottawa* Jones, the type species. The midventral absence of the flange and apparent lack of ventral submarginal pits are unlike *I. ottawa* and suggest a relationship to *Hogmochilina* Solle 1935, to which this species is tentatively referred.

Occurrence.—"Harding sandstone, near Canyon City, Colorado," U.S.N.M. 68771. A specimen of *Isochilina subnodosa* Ulrich occurs on the same piece of sandstone.

Family APARCHITIDAE Jones, 1901

The family was diagnosed by Kay (1940, p. 240) as follows: "Valves similar; surface rather regularly convex, without distinct sulcus, but with subcentral or posteroventral muscle spot."

This was expanded and modified by Hessland (1949, p. 147) in the following terms:

> Non-sulcate, or with shallow sulci; length 1 to 3 mm.; valves equal to slight unequal, overlap along entire free margin or ventrally; larger valve grooved for reception of edge of left; greatest convexity ventral, median or dorsal; in some species dorsally umbonate; surface smooth, striate or punctate; shell wal

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EXPLANATION OF PLATE 61

FIG. *1*—*Isochilina ampla* Ulrich, lateral view of holotype an internal mold of a right valve, False dove limestone of Catheys, Trentonian, Nashville, Tenn., ×2.0.

2,3—*Hogmochilina coloradoensis* Ulrich and Swain, n. sp.; *2*, exterior of holotype right valve, ×3.0; *3* a,b, side and ventral views of a paratype right valve, ×3.1; "Harding sandstone, near Cañon City, Colo.," U.S.N.M. 68771,

4—*Isochilina latimarginata* (Jones), lateral and dorsal views of holotype left valve, after Jones, Silurian, England, ×1.5.

5—*Isochilina labrosa* (Jones), lateral and ventral views (after Jones) of a specimen from Chazyan at Hawkesbury, Ontario, ×3.1.

6,7—*Isochilina seelyi* (Whitfield); *6*, exterior of large left valve, after Jones, ×7.8; *7*a, exterior of small cracked right valve, ×7.8; *7*b, exterior of elongate right valve, ×7.8; *7*c, exterior of large left valve, ×7.8; *7*d, dorsal view of same specimen as *7*c, ×7.8; Birdseye limestone, possibly Chazyan in age, Providence Island, Lake Champlain.

8—*Isochilina signifera* Ulrich and Swain, n. sp.; a, exterior of paratype left valve, ×8.7; b, exterior of holotype left valve, ×9.2; "Ostracode zone" of "lower Chambersburg" limestone, Blue Springs, 7 miles SW of Mercersburg, Pa.

9—*Isochilina* sp., (after Jones), outline of right valve, ×4, enclosing two smaller figures, exterior of right valve, ×.14, and ventral view of right valve, ×1.4; Chazyan, Russell Twp., Ontario.

10—*Isochilina cristata* (Whitfield), exterior of right valve, Beekmantown, Cove Island, Lake Champlain, Vermont, ×10.3.

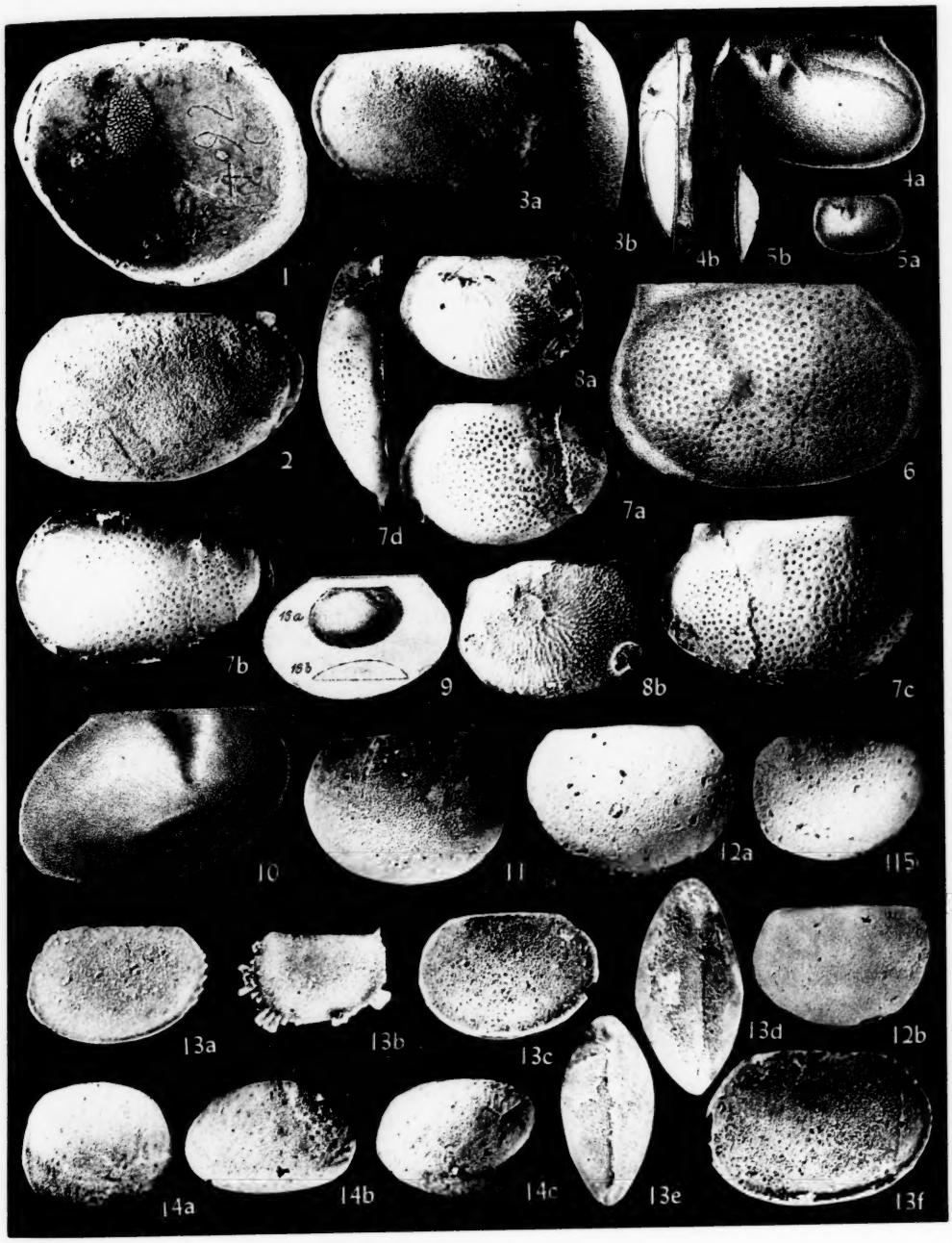
11—*Aparchites kauffmanensis* Swain, n. sp., exterior of right valve, New Market limestone, Kinter farm, 4 mi. NE of Marion, Pa., ×21.

12—*Aparchites pembertonensis* Swain, n. sp.; a, left side of holotype, ×30; b, left side of paratype ×21; Loysburg formation, approximately at base of Clover member, 235–246 feet above base of section, Union Furnace, Pa.

13—*Aparchites fimbriatus* Ulrich; a, exterior of a silicified right valve, ×21; b, exterior of an immature silicified right valve with many marginal spines, Crown Point formation, 40 feet above base, south end of Valcour Island, ×21; c, f, right side of two shells, Day Point formation 75–80 feet above base, south end of Valcour Island, ×21; d, e, dorsal views of two shells, Valcour formation, about 30 feet from top, north a[illegible] Valcour Island, ×21.

14—*Opikella frequens* (Steusloff); a, exterior of small left valve, middle part of Hostler member of Hatter formation, rib of quarry on Elk Run, 1½ miles S of Ironville, Pa., ×21; b, exterior of small left valve, near top of Snyder member of Benner formation, Union Furnace, Pa., ×21; c, exterior of small right valve, same locality as preceding, ×21.

15—*Leperditella mundula* (Ulrich), exterior of a right valve, Lower part of Clover member, Loysburg formation, Pemberton Quarries, Union Furnace, Pa., 245–246 feet above base, ×21.



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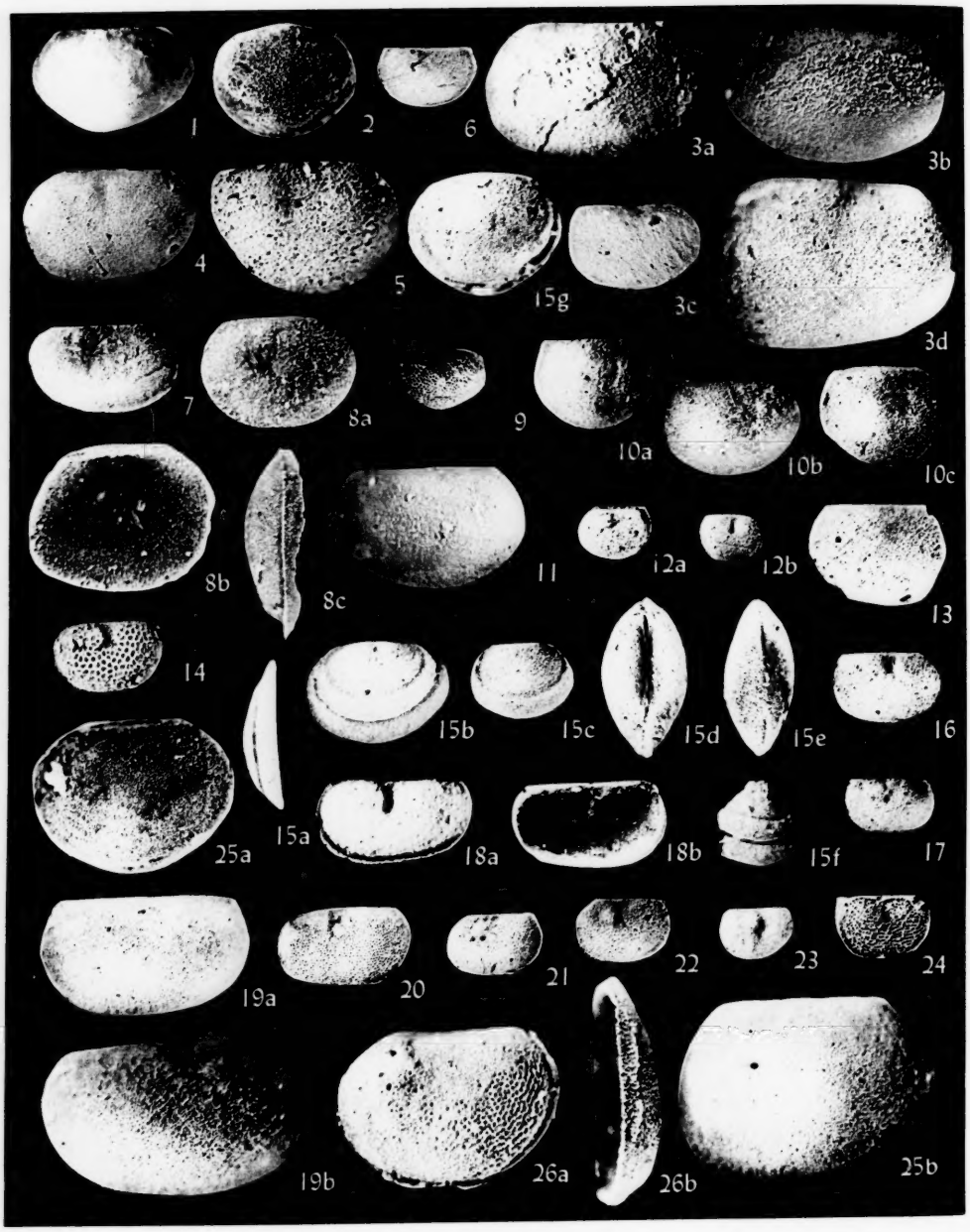
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EXPLANATION OF PLATE 62

FIG. *1*—*Eoleperditia fabulites* (Conrad), exterior of right valve. Middle part of Hostler member, Hatter formation, rib of quarry on Elk Run, 1¼ miles S of Ironville, Pa., ×7.8.

2—*Schmidtella crassimarginata* Ulrich, exterior of right? valve. Upper part of Cassin limestone, Beekmantown group, south end of Isle la Motte, ×21.

3—*Leperditella rex* (Ulrich), Coryell and Schenck; a, exterior of imperfectly preserved right valve, ×21; b, exterior of imperfect left valve, ×21; a, d, Snyder member, Benner formation 5–10 feet below top; b, c, basal Clover member, Loysburg formation, Pemberton quarry, Union Furnace, Pa.

4—*Leperditella aequilatera* (Ulrich), exterior of right valve. New Market limestone, 10–15 feet below top, 2 mi. SW of Kauffman, Pa. ×21.

5—*Leperditella mundula* (Ulrich), exterior of left valve, Basal layers of Loysburg formation, Pemberton quarries, Union Furnace, Pa., 198–199 feet above base of section, ×21.

6—*Saccelatia arrecta* (Ulrich), right side of a complete specimen. Day Point formation, 70–75 feet above base, southern end of Valcour Island, N. Y., ×21.

7—*Leperditella sulcata* (Ulrich), exterior of left valve, New Market limestone, 80–81 feet below top, Kinter farm, 4 mi. NE of Marion, Pa., ×21.

8—*Schmidtella incompta* Ulrich; a, exterior of silicified right valve; b, interior of silicified right valve; c, ventral view of silicified right valve; Crown Point formation, 35–40 feet above base, south end of Valcour Island, N. Y.; ×21.

9—*Aparchites kauffmanensis* Swain, n. sp., exterior of immature paratype right valve, Eyer limestone, quarry at Oakland School, south of Union Furnace, Pa., ×21.

10—*Primitiella* sp., exterior views of three right valves, New Market limestone, Kinter farm core hole, 4 mi. NE of Marion, Pa.; a and b from 80–85 feet below top, c from 79–80 feet; ×21.

11—*Aparchites pembertonensis* Swain, n. sp., exterior of a paratype right valve, Basal Clover member of Loysburg formation, Pemberton quarry, Union Furnace, Pa., ×21.

12—*Euprimita simplex* Swain, n. sp.; a, left side of paratype; b, exterior of holotype right valve; Day Point formation, 75–80 feet above base, south end of Talcour Island, N. Y.; ×21.

13—*Aparchites pembertonensis* Swain, n. sp., exterior of imperfect left valve, paratype, Day Point formation, 75–80 feet above base, south end of Valcour Island, N. Y., ×21.

14—*Euprimitia macropuncta* Swain, n. sp., exterior of silicified left valve, the holotype, Crown Point formation, 30–35 feet above base, south side of Valcour Island, N. Y., ×21.

15—*Cryptophyllus oboloides* (Ulrich and Bassler); a, ventral view ot silicified right valve Crown Point formation, 35–40 feet above base, south end of Valcour Island, N. Y., ×21; b, exterior of silicified right valve, same locality and horizon as a, ×21; c, exterior of small silicified right valve, Day Point formation, 75–80 feet above base, south end Valcour Island, ×21; d dorsal view of complete specimen, same horizon and locality as preceding, ×21, e, ventral view of complete specimen, basal Clover member, Loysburg formation Pemberton quarry, Union Furnace, Pa., ×30; f, exterior view of incomplete right? valve, having instar valve, same horizon and locality as preceding, ×21.

16—*Primitiella champlainensis* Swain, n. sp., exterior of holotype, right valve, Day Point limestone 80 feet above base, south side of Valcour Island, N. Y., ×21.

17—*Saccelatia* sp., exterior of a left valve, Lowville limestone, Chazy Lime and Stone Co. quarry, 1 mile S. of Chazy, N. Y., 26½–27 feet above base of section, ×21.

18—*Ectoprimitia pustulosa* Swain, n. sp.; a, exterior of left valve holotype; b, interior of paratype left valve; Crown Point formation 35–40 feet above base, south side of Valcour Island, N. Y.; ×21.

19—*Leperditella millepunctata* (Ulrich); a, exterior of a right valve, ×14; b, exterior of a left valve, ×21; New Market limestone, 20–25 feet below top, 2 mi. SW of Kauffman, Pa.

20,21—*Euprimitia millepunctata* Swain, n. sp.; *20*, exterior of holotype left valve, ×21; *12*, exterior of small paratype left valve, ×21; Day Point formation, 75–80 feet above base, south side of Valcour Island, N. Y.

22,23—*Conchoprimites ovoides* Swain, n. sp.; *22*, exterior of holotype left valve, Day Point formation 75–80 feet above base, south end of Valcour Island, N. Y., ×30; *23*, exterior of paratype right valve, Crown Point formation, 35–40 feet above base, south end of Valcour Island, ×21.

24—*Euprimitia labiosa* (Ulrich), exterior of a right valve, Day Point formation, 75–80 feet above base, south side of Valcour Island, N. Y., ×21.

25—*Aparchites fimbriatus* (Ulrich); a, right side of a complete shell, Day Point formation, 133–135 feet above base, southeastern part of Isle La Motte, Vt. ×21; b, exterior of right valve, upper Snyder member of Benner formation, Pemberton quarries, Union Furnace, Pa., ×21.

26—*Conchoprimitia öpikana* Swain, n. sp., exterior and ventral views of holotype left valve, Crown Point formation, 35–40 feet above base, south end of Valcour Island, N. Y. ×21.

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in some instances formed of an inner nonstructured and an outer prismatic part.

Geologic range.—Ordovician to Permian.

Genus APARCHITES Jones 1889

Ulrich and Bassler (1923, p. 296) diagnosed the genus as follows: "Shell not exceeding 3 mm. in length, equivalved, subovate or oblong, hinge straight, ventral edge thickened, often bevelled or channelled; surface convex, mostly in ventral half, smooth."

Type species.—*A. whiteavesi* Jones.

Geologic range.—Ordovician to Silurian.

APARCHITES KAUFFMANENSIS Swain, n. sp.
Pl. 61, fig. 11; pl. 62, fig. 9

Shell subquadrate in side view, highest medially; dorsal margin straight with distinct cardinal angles, the anterior a little more obtuse than the posterior; ventral margin strongly convex, terminal margins broadly and almost equally rounded, the anterior slightly extended above, and the posterior extended medially. Valves moderately convex, with greatest convexity midventral, surface sloping steeply to ventral margin.

Free margin of right valve slightly thickened and ridgelike presumably to receive overlapped edge of left. A small elliptical elevation occurs anteromedially and probably represents position of adductor muscle scar. General surface except free marginal band finely and densely pitted. Minute nodes or papillae occur along ventral margins of some specimens, in others they are absent.

Length of holotype, a right valve, 1.43 mm., height 0.97 mm., convexity 0.40 mm.

Remarks.—The short, high shell outline, punctate surface, anteromedian muscle scar elevation, and ventral papillae are features that characterize this species. *A. granilabiatus* (Ulrich) of the Decorah shale is similar in shape and marginal papillae but has a postulose rather than a punctate surface.

Occurrence.—The Chazyan deposits have yielded the species in the following places: Loysburg formation, Clover member, basal part, Pemberton quarries, Union Furnace, Pennsylvania; Day Point formation, 75–80 feet above base, south end of Valcour Island, New York; New Market limestone 20–25 feet below top, Diehl farm, 2 mi. SW of Kauffman Pa., and 80–81 feet below top, Kinter farm, 4 mi N of Marion, Pa.

APARCHITES PEMBERTONENSIS Swain, n. sp.
Pl. 61, fig. 12a,b; pl. 62, fig. 11

Shell subovate in lateral view, highest medially; dorsal margin nearly straight, about three-fourths of shell length, with well defined, nearly equally obtuse cardinal angles; ventral margin strongly convex; anterior margin broadly rounded, extended above, truncate below; posterior margin broadly rounded, extended medially. Valves moderately convex, greatest convexity posteromedian; anterior third slightly compressed. Right valve larger than left, overlapping and extending beyond the other along free margins; dorsally, left valve extends slightly beyond, and probably overlaps, right. Mid-dorsally, surface of each valve slightly swollen.

Length of holotype 1.5 mm., height 1.05 mm., convexity 0.71 mm.

Remarks.—The slight mid-dorsal swelling of this species is a feature resembling that in *Schmidtella*, with which there is probably a close relationship. In general shape, overlap, and compressed anterior part, it is similar to *Leperditella macra* (Ulrich) of the Decorah shale, but it lacks the mid-dorsal depression supposed to occur in *Leperditella*.

Occurrence.—Ranges from basal Clover member of Loysburg formation to middle part of Benner formation in Pemberton quarry, Union Furnace, and nearby Oakland School and Elk Run sections, Pennsylvania; Loysburg formation, quarry of New Enterprise Stone and Lime Company 1.8 miles south of Orbisonia, Pennsylvania; Upper part of New Market limestone, 39–44 feet below top, Chamberlain farm 1 mile west of Kauffman, Pennsylvania, and on Kinter farm 80–81 feet below top of New Market, 4 miles north of Marion, Pennsylvania; rare in Crown Point formation, 30–35 feet above base, south end of Valcour Island, New York.

APARCHITES FIMBRIATUS (Ulrich)
Pl. 61, fig. 13a–e

Leperditia fimbriata Ulrich, 1892, Am. Geol., v. 10, p. 268, pl. 9, fig. 34–36.

Aparchites fimbriatus Ulrich, 1894, Final Rept.,

Geol. and Nat. Hist. Surv. Minn., v. 3, p. 645, pl. 45, fig. 10–12; Grabau and Shimer, 1910, N.A. Index Fossils, p. 343, test-fig. 1657b; Bassler, 1915, U. S. National Museum Bull. 92, p. 53; Ladd, 1928–30, Iowa Geol. Surv., v. 34, p. 39; Kraft, 1957, Geol. Soc. Am., manuscript.

Aparchites carinatus Kay, 1940, Jour. Paleont. v. 14, p. 244, pl. 29 fig. 29–32.

?Leperditella canalis Ulrich, 1894, Final Rept., Geol. and Nat. Hist., Surv. Minn., v. 3, p. 637, pl. 43, fig. 1–3.

This species was thoroughly described by Kraft who pointed out the dissimilarity of the valves, the left bearing a broad frill in the immature stages which is reduced to a velate ridge in the adult; the right with a weak marginal ridge. The species is common and long ranging in the Ordovician, occurring as early as the Chazyan Day Point formation of New York and as late as the Maquoketa of Iowa-Minnesota.

Genus Öpikella Thorslund, 1940

The genus was diagnosed by Thorslund (1940, p. 181) as follows: "Similar to *Macronotella*, but valves subelliptical in outline with straight hinge and lacking a centrodorsal inflation. Surface usually with minute punctation instead of reticulate."

Additional characterization of the genus was made by Kraft (1957) in the following terms:

> Male specimens are characterized by a ventral velate ridge or narrow frill, female specimens bear a strong velate ventral frill. Valves are subequal, often with greater height anteriorly. Left valve slightly overlaps right valve along entire free margin. Muscle scars and punctae are not characteristic and may or may not be present.

Type species.—*O. tvaerensis* Thorslund, probably including *O. asklundi* Thorslund, the frilled dimorph.

Öpikella frequens (Steusloff)
Pl. 61, fig. 14a–c

Isochilina frequens Steusloff, 1894, Deutsch. Geol. Ges. Zeitschr., v. 46, p. 784, pl. 58, fig. 4. (See also Bassler and Kellett, 1934, p. 339, and Henningsmoen, 1954, p. 93.)

Aparchites frequens (Steusloff), Henningsmoen, 1954, Norsk Geologisk Tidsskr., v. 33, p. 93, pl. 5, fig. 7–9; Kraft, 1957, Geol. Soc. Am., in manuscript.

Detailed descriptions of this species have been given by Henningsmoen and Kraft. The specimens illustrated are probably immature molts in which the frill of the female is just beginning to appear.

Occurrence.—In the present collections, the species occurs questionably in the basal Clover member, Loysburg formation; and in the Crown Point formation 30–35 feet above base, Valcour Island, New York. Kraft (1957) found it in the Lincolnshire and lower half of the Edinburgh formations of the Shenandoah Valley, Virginia. The following occurrences in Europe were recorded by Henningsmoen 1954 (p. 94): Upper Ordovician, stages 5a, 5b, Dalmanitinea Series, Oslo region, Norway; Ordovician *Leptaena* limestone and Algal limestone North Germany; Ordovician Porkuni limestone, Esthonia.

Genus Saccelatia Kay, 1940

According to Kay (1940, p. 244) the genus has "Valves small, similar; outline deeply truncate, elliptical, hinge straight, relatively long, ends subequal. Valves quite convex, surface rising gently from dorsal margin to greatest thickness ventral to midheight; surface smooth or with fine reticulation, having ventral swellings, flanges and projections in some species. Contact with left valve overlapping; bordered by marginal granules in some species."

Type species.—*Aparchites arrectus* Ulrich, 1894.

Geologic range.—Ordovician.

Saccelatia arrecta (Ulrich)
Pl. 62, fig. 6

Aparchites arrectus Ulrich, 1894, Final Rept., Geol. and Nat. Hist. Surv., Minn., v. 3, pt. 2, p. 646, pl. 43, fig. 35, 36.

Saccelatia arrecta (Ulrich), Kay, 1940, Jour. Paleont; v. 14, p. 243, pl. 29, fig. 12–16.

The species was described in detail by Ulrich and Kay. The specimen figured here is a representative of the Chazyan material, but may be an immature molt since it most resembles Kay's figures 15 and 16.

Length of figured specimen 0.66 mm., height 0.38 mm., convexity 0.14 mm.

Occurrence.—Day Point formation, 70–75 feet above base, southern end of Valcour Island, New York; Hostler member of Hatter formation, Pemberton quarries, Union Furnace, Pennsylvania. Originally described from the "Upper third of Trenton shales," it was referred by Kay (1940, p. 243) to the

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Ion member of Decorah shale, near Cannon Falls, Minnesota.

Superfamily BEYRICHIACEA
Family PRIMITIIDAE

Although recent changes in the nomenclature of the primitiid ostracodes of the subfamily and family categories have been made (Hessland, 1949, Henningsmoen 1953), the description of the family given by Swartz (1936, p. 549) is employed here:

> Small, straight-backed, unisulcate Ostracoda; outline subrhomboidal; cardinal angles distinctly unequal; surface in some species with low swellings near sulcus, and in part with weak rim or false border along free edges; hingement essentially simple; overlap wanting or inconspicuous; sexual dimorphism unknown.

Geologic range.—Ordovician to Permian.

Genus LEPERDITELLA Ulrich, 1894

The genus was described by Ulrich (1894, p. 636) as follows: "Carapace leperditoid, ovate or oblong, with a straight back; surface of valves without eye tubercle but a more or less obscure broad depression is generally present in the central part of the dorsal half; left valve a little larger than the other; the free edges of the latter fitting into a groove. Length 1 to 3 mm."

Type species.—*Leperditella rex* Coryell and Schenck, new name for *Leperditia inflata* Ulrich, (1892, p. 265) not *L. inflata* (Murchison) (Jones 1854, p. 54) or *L. inflata* (Münster) (Etheridge, 1888, p. 241).

Geologic range.—Ordovician to Permian.

LEPERDITELLA REX (Ulrich), Coryell and Schenck
Pl. 62, fig. 3a–d

Leperditia inflata Ulrich, 1892, Am. Geol., v. 10, no. 5, p. 265, pl. 9, fig. 12–15. Not *Cypris inflata* (Murchison, 1839, Silurian Syst., p. 84; fig. a1–3, =*Leperditia inflata* (Murchison), Jones and Kirkby, British Assoc. Rept. for 1863 (1864) p. 80, =*Paraparchites inflatus* Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper 1, p. 426.

Leperditella inflata Ulrich, 1894, Geol. and Nat. Hist. Surv., Minn., v. 3, pt. 2, p. 636, fig. 46a–d. (see Bassler and Kellett, 1934 for additional synonmy.

Leperditella rex Coryell and Schenck, new name, 1941, Jour. Paleontology, v. 15, no. 2, p. 177.

Shell subovate to subreniform in lateral view, highest about one-third of length from posterior end; dorsal margin slightly concave anteromedially with very gradual cardinal marginal bends; ventral margin moderately convex; terminal margins rounded, the anterior narrower and subtruncate above; valves subequal, rather strongly convex with greatest convexity posteromedian.

A broad shallow sulcus occupies dorsal third of each valve anterad of middle; posterior dorsal surface swollen to extend somewhat beyond hinge line; Adductor muscle scar very large, oval, elongate dorsoventrally, and apparently contains numerous tiny spots. General surface smooth.

Length of a figured right valve (pl. 62, fig. 3d) 1.63 mm., height 1.06 mm.

Remarks.—This species probably represents a basic stock from which some sulcate later Ordovician and Silurian ostracodes descended. The general shape is reminiscent of some of the more primitive kloedenellids, to which the genus is possibly ancestral.

Occurrence.—At Union Furnace, Pennsylvania, the species was obtained from the Loysburg, Hatter and Benner formations and occurs in both the *Aparchites kauffmanensis* and *Monoceratella teres* zones. On Valcour Island, New York, it is sparsely represented in the *Monoceratella teres* zone of the middle Crown Point formation.

LEPERDITELLA AEQUILATERA (Ulrich)
Pl. 62, fig. 4

Leperditia aequilatera Ulrich 1892, Am. Geol., v. 10, p. 265, pl. 9, fig. 9–11.

Leperditella aequilatera Ulrich, 1894, Final Rept., Geol. and Nat. Hist. Surv. Minn., v. 3, pt. 2, p. 636, text-fig. 46i., Bassler, 1915, U. S. National Museum, Bull. 92, p. 696.

Shell subelliptical to subovate in side view, highest posteromedially; ventral margin moderately convex, anterior margin narrowly rounded, extended above; posterior margin more broadly rounded, slightly truncated below. Valves moderately convex. Surface smooth except for a weak dorsomidventral sulcus.

Length of figured specimen 1.18 mm., height 0.75 mm., convexity 0.56 mm.

Remarks.—The small size and the shape of this species bear a resemblance to *Primitiella*, but the weak, broad nature of the sulcus is more leperditellid. The species is close to *L. sulcata* (Ulrich) but its sulcus is weaker and its surface tapers more gradually to the margins.

Occurrence.—Originally described from the "Birdseye" limestone at High Bridge,

Kentucky. The species is recorded here from the upper part of the New Market formation, Chazyan, 10-15 feet below top, Diehl farm, 2 mi. SW of Kauffman, Pa. The High Bridge occurrence is now referred (Twenhofel et al, 1954, col. 44) to the Camp Nelson limestone, Black Riveran.

LEPERDITELLA MUNDULA (Ulrich)
Pl. 62, fig. 5

Leperditia mundula Ulrich, 1892, Am. Geol., v. 10, p. 265, pl. 9, fig. 4–8.
Leperditella mundula Ulrich, 1894, Geol. and Nat. Hist. Surv., Minn., v. 3 pt. 2, p. 636, fig. 461–h; Bassler, 1915, U. S. Nat. Mus., Bull. 92 p. 696.

Shell subovate in side view, highest slightly posterior to midlength, dorsal margin nearly straight with slightly obtuse, distinct anterior cardinal angle and more obtuse, rounded posterior angle; ventral margin strongly convex; anterior margin much narrower than posterior but its actual curvature is fairly broad. Valves subequal, convexity moderate, greatest ventromedially. Broad shallow median sulcus present in dorsal half. General surface smooth.

Length of figured left valve 1.33 mm., height 0.85 mm.

Remarks.—This species has a subtriangular shape like that in *L. tumida* (Ulrich), but it is more evenly convex, has a deeper median sulcus, and is slightly more elongate than that species.

Occurrence.—Lower part of Loysburg formation in the lower Clover and "tiger-striped" beds, Pemberton quarries, Union Furnace, Pa., and in middle Hostler member of Hatter formation, rim of quarry on Elk Run, 1½ miles south of Ironville, Pennsylvania. Originally described from "Birdseye" limestone near bottom of river gorge, High Bridge Kentucky; (now classified as Camp Nelson limestone, Black Riveran).

LEPERDITELLA SULCATA (Ulrich)
Pl. 62, fig. 7

Leperditia sulcata Ulrich, 1892, Am. Geol., v. 9, p. 266, pl. 9, fig. 19–20,21.
Leperditella sulcata Ulrich, 1894, Final Rept. Geol. and Nat. Hist. Surv., Minn., v. 3, pt. 2, p. 636, text-fig. 46j; Bassler, 1909, Va. Geol. Surv., Bull. 2a, pl. 23, fig. 14; 1915, U.S. Nat. Mus., Bull. 92, p. 697.

Shell subelliptical in side view, highest posteromedially; hinge margin straight, with obtuse somewhat rounded cardinal marginal bends; ventral margin moderately convex; anterior margin narrowly rounded, extended above; posterior margin more broadly rounded, slightly extended below; valves subequal, not strongly convex, greatest convexity posteromedian.

Median sulcus broad and shallow, occupying dorsal half and lying a little anterad of midlength. Free margins with low bordering ridge. General surface smooth.

Length of figured specimen 0.96 mm., height 0.50 mm.

Remarks.—The species is close to *L. aequilatera* in outline but is more deeply sulcate and bears a submarginal ridge.

Occurrence.—Upper part of New Market limestone 80–81 feet below top, Kinter farm, 2 miles SW of Kauffman, Pennsylvania, also middle part of underlying Row Park limestone, Lehman farm, 1 mile west of Kauffman, Pennsylvania. Originally described from Black Riveran limestone at High Bridge, Kentucky, it has also been reported from Tennessee and Virginia.

LEPERDITELLA MILLEPUNCTATA (Ulrich)
Pl. 62, fig. 19a,b

Leperditia millepunctata Ulrich, 1892, Amer. Geol., v. 10, p. 268, pl. 9, fig. 37–39.
Aparchites millepunctatus (Ulrich), 1894, Geol. and Nat. Hist. Surv. of Minn., Final Rept. v. 3, p. 645, pl. 45, fig. 16–18; Bassler and Kellett, 1934, Geol. Soc. Am., Spec. Paper 1, p. 159.

Shell subelliptical in lateral view, highest medially; dorsal margin straight, about three-fourths of shell length, cardinal angles obtuse, the anterior somewhat less so than the posterior; ventral margin moderately convex; terminal margins almost equally rounded, the anterior slightly extended above, the posterior extended medially, truncated above. Valves moderately convex, greatest convexity slightly antero-midventral. Overlap not observed.

Free margin of left valve bears a weak narrow submarginal ridge. Mid-dorsally there is a very shallow inconspicuous depression. Circular adductor muscle area lies about two-fifths of length from anterior end and venterad of midheight. Entire surface, including muscle area, very finely and closely pitted.

Length of figured specimen 1.68 mm., height 0.88 mm., convexity 0.50 mm.

Relationships.—The shape and obscure mid-dorsal depression relate this species to

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Leperditella Ulrich rather than to *Aparchites* Jones. The finely punctate surface was considered by Ulrich (1894, p. 645) to distinguish the species from *L. aequilatera* Ulrich, to which it conforms in general shape.

Occurrence.—Originally described from the "lower or middle third of the Trenton (Decorah) shales, near Fountain, Minnesota." In the present collections the species is found in the New Market limestone, 20–25 feet below top, Diehl farm, 2 mi. SW of Kauffman, Pa.; questionably in basal Clover member of Loysburg formation, Pemberton quarry, Union Furnace, Pa.

Genus SCHMIDTELLA Ulrich, 1892

Ulrich (1894, p. 639) modified his original description approximately as follows: "Shell typically less than 2 mm. long; subovate, moderately convex, with greatest convexity in dorsal region; dorsum umbonate; right valve slightly the larger, and overlapping the other ventrally. A faint central pit and elevation occurs in some species."

Retention of immature molts in dorsal region has recently been demonstrated (Levinson, 1951) in this general group of ostracodes.

Type species.—*Schmidtella crassimarginata* Ulrich.

Geologic range.—Ordovician.

SCHMIDTELLA CRASSIMARGINATA Ulrich
Pl. 62, fig. 2

Schmidtella crassimarginata Ulrich, 1892, Am. Geol., v. 10, p. 269, pl. 9, fig. 27–30. (See Bassler and Kellett, 1934, p. 471, for additional synonymy.)

In side view shell suboval, highest medially; dorsal margin slightly convex with a low umbo medially; ventral margin strongly convex; terminal margins broadly rounded, the anterior slightly narrower than posterior. Valves not strongly convex. Hinge margin recessed and overreached by umbos. A furrow masking free edge of an earlier instar. Valve roughly parallels margin beginning ventrad of cardinal angles. General surface smooth.

Length of figured right valve 0.93 mm., height 0.73 mm.

Remarks.—This form is similar to frilled dimorphs of *Öpikella frequens* in outline and presence of a submarginal furrow, but is less convex and its ventral surface is not flared outward as in *Ö. frequens*. *Cryptophyllus oboloides* in advanced growth stages from which earlier instar valves have been shed is likewise similar, but is weakly sulcate dorso-medially.

Occurrence.—Upper part of Cassin limestone, Beekmantown group, Lower Ordovician, south end of Isle LaMotte, Vermont. Originally described from Black Riveran Platteville limestone at Mineral, Wisconsin, the species has also been recorded from the Black Riveran Lebanon limestone of Alabama, and from the Chazyan, Valcour Island, New York.

SCHMIDTELLA INCOMPTA Ulrich
Pl. 62, fig. 8a–c

Schmidtella incompta Ulrich, 1894, Final Rept. Geol. and Nat. Hist. Surv., Minn., v. 3, pt. 2, p. 642, pl. 45, fig. 27,32,33 (not pl. 13, fig. 39–41); Bassler, 1915, U. S. Nat. Mus., Bull. 92, p. 1148; Kay, 1934 Jour. Paleontology, v. 14, p. 329, 1940, ibid., p. 242, pl. 29, fig. 5,6.

Descriptions of the species were provided by Ulrich and by Kay. Principal differences from other speces of *Schmidtella* are the lack of prominent dorsal umbonation, and presence of a very slight sulcus-like depression of the dorsal surface.

Length of a figured right valve 0.64 mm., height 0.45 mm.

Occurrence.—In the present collections this species occurs silicified in the Crown Point formation, 35–40 feet above base, southern end of Valcour Island, New York, and in the Hatter and Benner formations, Union Furnace, Pennsylvania. It was originally described from the "lower part of the Trenton shales" and Kay has placed it in the Guttenberg member, Decorah formation, near Fountain, Minn.

Genus CRYPTOPHYLLUS Levinson, 1951

The genus was described in detail by Levinson (1951, p. 558). Shell ovate to subquadrate, dorsally umbonate, with dorsomedian weak to strong V-shaped short sulcus. Immature instar valves frequently retained. External ornamentation consists of one or more concentric flat ridges, representing ventral parts of retained instar valves. Hinge of left valve formed of longitudinal ridge, dorsally adjacent prominent groove, and ventrally adjacent weak groove.

Type species.—*Eridoconcha oboloides* Ulrich and Bassler.

Geologic range.—Ordovician to Devonian.

CRYPTOPHYLLUS OBOLOIDES (Ulrich and Bassler)
Pl. 62, fig. 15a–f

Eridonconcha oboloides Ulrich and Bassler, 1923, Maryland Geol. Surv., Silurian vol., p. 296, text-fig. 14, fig. 6–8.
Cryptophyllus oboloides (Ulrich and Bassler), Levinson, 1951, Jour. Paleont., v. 25, p. 558.

Shell elongate-subovate in side view; highest medially to anteromedially; dorsal margin nearly straight in exfoliated specimens, convex in those retaining early "molts"; cardinal angles obtuse, the anterior more so than posterior; ventral margin gently to moderately convex, anterior margins rather narrowly rounded, extended medially to dorsomedially, projecting well beyond end of hinge; posterior margin more broadly rounded, slightly extended below. Left valve slightly larger than right, overlapping it ventrally. Valves moderately convex with greatest convexity median.

The shell of the species is characterized by retention of two or three immature instar valves; the earlier of which produce prominent umbonation mid-dorsally; free margins of each instar valve, possibly excepting the first which has not been seen, bears a broad, slightly elevated rim, the inner margin of which provides a seat for outer margin of next earlier instar valve; mid-dorsally in smaller instar valves, and anterodorsally in more mature valves, is a small pitlike sulcus.

Length of figured right valve (pl. 62, fig. 15b) 0.77 mm. height 0.65 mm.

Occurrence.—The species was originally described from the Decorah shale, Mohawkian, of Minnesota. In these collections it occurs in the Clover member of the Loysburg and Eyer member of the Hatter formations at Union Furnace, Pennsylvania, in the Upper Benner formation, Colerain, Pennsylvania, and in the upper Beekmantown, Day Point, and lower and middle Crown Point of Valcour Island, N.Y. and Isle La Motte, Vermont. Cornell (1956) found it occurring throughout the Decorah shale of Minnesota. It also extends into Richmond group of Indiana and Ohio.

Genus PRIMITIELLA Ulrich, 1894

Shell subelliptical, elongate in outline, nearly equivalved, compressed to moderately convex; antero-median sulcus in dorsal half, broad, shallow; free marginal zone without differentiated border or very slightly compressed; surface smooth or finely punctate.

Type species.—*Primitiella constricta* Ulrich.

Geologic range.—Ordovician to Devonian.

PRIMITIELLA sp.
Pl. 62, fig. 10a–c

Shell subovate-subquadrate in side view; highest medially; dorsal margin nearly straight to slightly sinuous, with poorly defined, broadly obtuse, anterior cardinal angle and sharper, much less obtuse, posterior cardinal angle, ventral margin moderately convex; anterior margin rounded, extended dorsomedially, truncated above; posterior margin more broadly rounded extended medially to ventromedially.

Valves subequal, moderately convex. A shallow, broad sulcus occurs anterior to midlength in dorsal half. A narrow marginal flange is present along dorsal two-thirds of posterior margin; anterior margin bears a similar narrow flange in some specimens. Surface otherwise smooth. Adductor muscle scar lies in lower part of sulcus, is large, oval, and contains numerous small spots.

Length of figured specimen (pl. 4, fig. 10c) 0.88 mm., height 0.57 mm., convexity 0.46 mm.

Occurrence.—Originally described by Kraft from the Lincolnshire and lower half of Edinburg formations, Chazyan, at Strasburg, Virginia; in present collections in New Market formation 80–81 feet below top, Kinter farm, 4 miles north of Marion, Pennsylvania.

PRIMITIELLA CHAMPLAINENSIS Swain, n. sp.
Pl. 62, fig. 16

Shell ovate in side view; highest medially, dorsal margin nearly straight with strongly obtuse anterior, and only slightly obtuse posterior, cardinal angles; ventral margin gently convex; anterior margin rounded, extended medially, truncate above; posterior margin very broadly curved.

A small shallow pitlike sulcus occurs middorsally, not reaching to dorsal margin. General surface smooth.

Length of holotype, a right valve, 0.72

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mm., height 0.41 mm., convexity of valve 0.17 mm.

Remarks.—The weak sulcus, outline and lack of distinct false border are indicative of *Primitiella* rather than of *Euprimitia*, which is suggested by the pitlike nature of the sulcus, and lack of nodelike swellings on either side of sulcus as in *Primitia*. Its generic position is nevertheless questionable.

Occurrence.—Day Point and lower Crown Point formations, south end of Valcour Island, New York.

Genus EUPRIMITIA Ulrich, 1894

Shell subovate, straight hinged, pitlike dorsomedian sulcus; free margins typically with elevated, smooth false border; surface smooth or pitted.

Type species.—*Primitia sanctipauli* Ulrich.

Geologic range.—Ordovician to Silurian.

EUPRIMITIA SIMPLEX Swain, n. sp.
Pl. 62, fig. 12a,b

Shell subovate in side view, highest about one-fourth from posterior end; hinge margin straight, about two-thirds of shell length; with broadly obtuse anterior cardinal angle and much less obtuse posterior cardinal angle; ventral margin moderately convex merging gradually with anterior margin and abruptly with posterior margin; anterior margin rounded, extended medially; posterior margin more broadly rounded, subtruncate below. Valves subequal, moderately convex; greatest convexity posteromedian.

A narrow subvertical sulcus, open dorsally, occupies dorsal two-fifths of valve; ventral termination is pitlike; posterior end compressed; posterior surface slopes steeply to margin; anterior border with faint, broad, smooth rim; surface very weakly pitted.

Length of holotype, a right valve, 0.52 mm., height 0.43 mm., convexity 0.12 mm.

Remarks.—This species is similar to *E. sanctipauli* (Ulrich) in general shape, sulcation, and lack of raised marginal rim but is smaller, more weakly ornamented, and less convex posteriorly. The specimen figured by Öpik (1938, pl, 13, fig. 30) as *Haploprimitia kiogermani* Öpik, from the Ordovician of Esthonia, may belong to this species.

Occurrence.—The holotype is from 75 feet above base of Day Point formation, southern end of Valcour Island.

EUPRIMITIA MACROPUNCTA Swain, n. sp.
Pl. 62, fig. 14

Shell subovate in lateral view, highest posteromedially; dorsal margin nearly straight, and about seven-eights of shell length; anterior cardinal angle not well defined, broadly obtuse; posterior cardinal angle more distinct and much less obtuse; ventral margin moderately convex, straightened medially; terminal margins broadly rounded, the anterior extended medially, the posterior slightly extended above. Valves apparently subequal, moderately convex, greatest convexity posteromedian.

A sulcus of medium depth and width extends from near margin to about one-third distance from dorsum; a rounded node lies anterior to sulcus. Marginal areas smooth; midportion of valve, including node, coarsely reticulate.

Length of holotype, a left valve, 0.47 mm., height 0.29 mm., convexity 0.11 mm.

Relationships.—The large pits produced by surface reticulation, serve to distinguish this species from others of the genus.

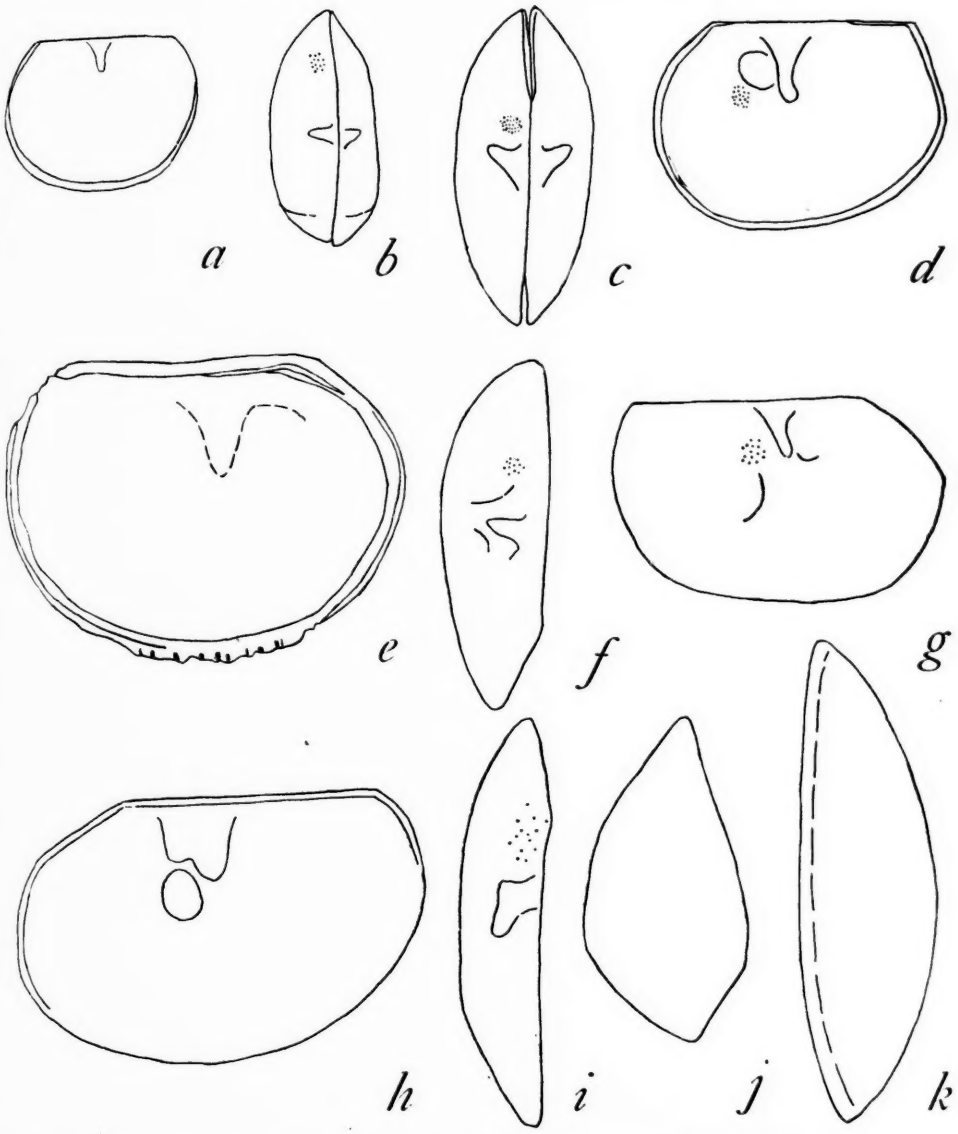
Occurrence.—The holotype is from the Crown Point formation 30–35 feet above base, south side of Valcour Island, New York.

EUPRIMITIA MILLEPUNCTATA Swain, n. sp.
Pl. 62, fig. 20,21

Shell subelliptical-subquadrate in lateral view, highest one-fourth to one-third from posterior end; hinge margin nearly straight, about three-fourths of shell length, with rounded cardinal marginal bends, the anterior more obtuse than the posterior; ventral margin slightly convex, subparallel to dorsum; anterior margin rounded, extended medially; posterior margin slightly more broadly rounded, extended above. Valves subequal; convexity of valve surfaces moderate, greatest convexity posteromedian.

A very shallow, weak, broad sulcus lies in dorsal third, slightly anterad of midlength; at base of sulcus and within it lies a low rounded swelling that perhaps represents location of adductor muscle attachment. Posterior and posteroventral margins provided with very narrow rim; general surface finely punctate more or less in a reticulate pattern.

Length of holotype, a right valve, 0.87



TEXT-FIG. *10*—CAMERA LUCIDA DRAWINGS OF LEPERDITIIDAE AND LEPERDITELLIDAE

a,b, *Euprimitia simplex*, Swain, n. sp., right side and dorsal views of holotype, Day Point formation, 75–80 feet above base, Valcour Island, New York.

c,d, *Conchoprimites ovoides* Swain, n. sp., dorsal and right side views of holotype, showing anteromedian low node, Crown Point formation, 35–40 feet above base, Valcour Island, N. Y.

e, *Conchoprimitia öpikana* Swain, n. sp., interior of holotype left valve showing anterior hinge groove and weak ventral notched velum, Crown Point formation, 35–40 feet above base, Valcour Island, N. Y.

f,g, *Primitiella champlainensis* Swain, n. sp., dorsal and exterior views of holotype right valve, Day Point limestone, 80 feet above base, Valcour Island, N. Y.

h,i, *Euprimitia millepunctata* Swain, n. sp., exterior and dorsal views of holotype left valve, Day Point formation, 75–80 feet above base, Valcour Island, N. Y.

j,k, *Eoleperditia fabulites* (Conrad), anterior and ventral views of a left valve, lower Clover member, Loysburg formation,

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mm., height 0.54 mm., convexity of valve 0.17 mm.

Relationships.—This species has the general shape of *E. sanctipauli* (Ulrich) but is much more finely punctate. It is also very close to *Primitiella? champlainensis*, n. sp., of this paper, but that species is impunctate and lacks the short marginal keel.

Occurrence.—Day Point formation 75–80 feet above base, south end of Valcour Island, New York.

EUPRIMITIA LABIOSA (Ulrich)
Pl. 62, fig. 24

Halliella labiosa Ulrich, 1894, Final Rept. Geol. and Nat. Hist. Surv., Minn., v. 3, pt. 2, p. 656; Kay, 1934, Jour. Paleont., v. 8, p. 332, pl. 44, fig. 17,18.
Euprimitia labiosa (Ulrich) Kay, 1940, Jour. Paleont., v. 14, p. 252, pl. 31 fig. 16–18; Kraft, 1957, Geol. Soc. Am., in manuscript.

The species was thoroughly described by Kay. Its distinguishing features are the small, pitlike, mid-dorsal sulcus, smooth marginal area and densely reticulated surface. The obtuse anterior cardinal angle and nearly acute posterior cardinal angle are significant.

Length of figured right valve, 0.64 mm., height 0.40 mm.

Occurrence.—The species was described from the middle and upper Decorah shale, Trentonian, of Minnesota and has also been found in the Hull formation of Ontario (Kay, 1934) and the Lincolnshire and lowermost Edinburg formation, Chazyan, Shenandoah Valley, Virginia. (Kraft, 1957). In this collection it is present in the Day Point and lower Crown Point formations, Chazyan, of Valcour Island, New York.

Genus ECTOPRIMITIA Bouček, 1936

Haploprimitia (*Ectoprimitia*) Bouček, 1936, Neues Jahrb. Min. Beil-Bd. 76, Abt. B, p. 45.
Ectoprimitia Schmidt, 1941, Senckenberg. Natureforsch. Ges. Abh., 454, p. 26.

Shell similar to *Primitiella* in shape but with deeper sulcus; sulcus extended to dorsal margin, and with more distinctly compressed free marginal areas.

Type species.—*Primitia corrugata* Krause.
Geologic range.—Ordovician.

ECTOPRIMITIA PUSTULOSA Swain, n. sp.
Pl. 62, fig. 18a,b

Shell subelliptical in side view, highest about one-fourth from anterior end; hinge margin straight, about five-sixths of shell length, cardinal angles distinct, the anterior less obtuse than the posterior; ventral margin slightly convex, straightened medially; terminal margin, broadly rounded, the posterior somewhat the narrower. Valves subequal, not strongly convex, greatest convexity ventromedial.

Free margins with narrow, submarginal thin frill or velum. Mid-dorsally there is a lachrymose deep sulcus, curved toward anterior, deepest ventrally and with anterior flank steeper than posterior. General surface bears scattered low postules. Hinge surface consists of simple contact of valves with triangular flattened terminal elements.

Length of holotype, a left valve (pl. 62, fig. 18a), 0.62 mm., height 0.29 mm., convexity 0.17 mm.

Relationships.—This species is similar to *E. diminucarina* Kraft from the Lincolnshire and Edinburgh formations of Virginia, but that species has a rounded swelling anterad of the sulcus and lacks pustulation of the surface.

Occurrence.—The holotype is from the Crown Point formation, 40 feet above base, southern end of Valcour Island, New York

Genus CONCHOPRIMITIA Öpik, 1935

Conchoides Hessland, 1949, Geol. Inst. Upsala, v. 33, p. 149 (by Henningsmoen, 1953).

Kraft (1957) diagnosed the genus as follows:

> Outline subovoid in lateral view, with subequal ends or slightly leperditoid; left valve overlaps right; one or two faint concentric grooves on lateral surface sometimes reflect previous molts; surface smooth, on some specimens a faint sulcate depression is present anterodorsally; on *E. asymmetrica* . . . an internal subvertical ridge is present; two "blood grooves" radiating from the adductor muscle scar can be seen on internal molds of some specimens.

Type species.—*Conchoprimitia gammae* Öpik.
Geologic range.—Ordovician.

CONCHOPRIMITIA ÖPIKANA Swain, n. sp.
Pl. 62, fig. 26a,b

Shell subovate in lateral view, highest medially; dorsal margin nearly straight to slightly concave; with broadly obtuse cardinal angles; ventral margin strongly con-

vex; anterior margin broadly rounded, extended medially, truncate above posterior margin also broadly rounded. Valves apparently subequal in size, not strongly convex, most convex posteromedially.

Hinge surface of right valve formed mainly of valve edge, but anteriorly a weak elongate socket impressed in edge of valve.

Surface of partly exfoliated(?) figured specimen bears broad shallow dorsomedian sulcus; a weak, short, subvertical ridge occurs anterodorsally; posteroventral surface densely and finely pitted; scattered pits occur ventromedially; a weak, anteriorly spinose, false keel occurs ventrally and anteriorly. Posteroventral surface elevated as a less conspicuous ridge paralleling margin.

Length of holotype, a right valve, 0.91 mm., height 0.65 mm.

Relationships.—Retention of early instar valves has been observed in conchoprimitiid ostracodes (Henningsmoen, 1953, p. 251). The posteroventral ridge of the present species may represent the site of the margin of such an early instar valve. These marginal features separate the species from *Leperditella*, to which it is otherwise closely related in shape and sulcation.

Occurrence.—Crown Point formation, 35–40 feet above base, south end of Valcour Island, New York.

Genus CONCHOPRIMITES Hessland, 1949

A diagnosis of the genus by Hessland (1949, p. 236) shows that it differs from *Conchoprimitia* in possessing a more distinct anteromedian sulcus, but in general shape and marginal features it resembles that genus.

Type species.—*C. reticulifera* Hessland.

Geologic range.—Ordovician.

CONCHOPRIMITES OVOIDES Swain, n. sp.
Pl. 62, fig. 22,23

Shell subovoid in lateral view, highest medially to anteromedially; dorsal margin straight, with obtuse, unequal cardinal angles, anterior much more strongly obtuse than posterior; ventral margin moderately convex, converging slightly toward posterior with respect to dorsum; anterior margin broadly rounded, truncated above; posterior margin slightly more narrowly rounded, extended medially. Valves unequal the left slightly larger, extending beyond right along free margins. Convexity moderate, greatest convexity ventromedian.

A broad shallow sulcus occupies dorsal two-fifths of each valve but nearly dies out near dorsal margin; a low circular node lies anterad of sulcus; a slight groove or marginal compressed zone occurs posteriorly in holotype; anteriorly this feature is very obscure but may be slightly developed. General surface very weakly reticulate.

Length of holotype 0.63 mm., height 0.43 mm., convexity 0.30 mm.

Relationships.—The new species is similar to *C. reticulata* Hessland, the type species, but has unequal ends and lacks the more complete marginal groove and reticulate surface of that species.

Occurrence.—Day Point formation, 80 feet above base, south side of Valcour Island, New York.

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A FAUNA FROM THE LOWER CRETACEOUS BARRANQUÍN FORMATION OF VENEZUELA

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ABSTRACT—A fauna consisting principally of fossil corals and mollusks was collected from the 1000 meters that comprise the upper two-thirds of the Barranquín formation on the islands to the north of the Bahía de Santa Fé, eastern Venezuela. Forty-eight species are described, including fifteen new species: *Astrocoenia minima, Gervillia maroma, Cardita cumanesa, Angaria keenae, Metriomphalus schwarki, Metriomphalus taguarumensis, Turritella ministeri, Turritella pelusae, Nerinaea dianae, Nerinaea riverae, Nerinaea trishae, Cerithium krauskopfi, Gymnocerithium lisum, Anchura catedralis*, and *Anchura sucrensis*. Three other species are considered new, but no name is given them due to the fact that the material is imperfect. The assemblage shows relationships both with the Neocomian fauna of Europe and the Albian fauna of North America, principally that of the Glen Rose formation of Texas. The Barranquín fauna is considered to have only a facies relationship with the North American fauna, underlying as it does Aptian ammonite horizons, and in consequence its age is thought to be Neocomian-Barremian.

INTRODUCTION

RELATIVELY little has been published on the Lower Cretaceous faunas of Venezuela and this is especially true of the Barranquín formation, which is an important lithologic unit of northeastern Venezuela. The fact that many of the rocks of the epoch are fossiliferous is mentioned widely in the pertinent literature, but generally only a few generic names and an occasional well-quoted species are given. This meagerness of information may be due to the general occurrence of the fossils in limestones, which appear commonly only as cross-sections on the weathered surfaces of the outcrops, thus preventing extensive study.

Under the special conditions prevalent along the sea-coast within two or three meters of the strand-line, the soft calcareous fossils are weathered out of the hard limestone matrix and are available in a remarkably good state of preservation. During the geologic mapping of the Bahía de Santa Fé region of eastern Venezuela, the writer was able to collect a great number of fossils from several localities of this type, thus obtaining one of the most varied assemblages of Barranquín fossils known.

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PREVIOUS WORK

The presence of fossils in the Barranquín formation was mentioned by Liddle (1928) at the time he described the formation. He reported the occurrence of rudistids, *Ostrea* resembling *O. subovata* Schumard, and *Exogyra boussingaulti* in Barranquín limestones five kilometers east of Cumaná. An earlier report of fossils, presumably in rocks later to be called Barranquín, was that of Wall and Sawkins (1860, p. 166). These authors mentioned *Peteroceras, Cerithium, Turritella, Trigonia subcrenulata* (=*T. hondaana*), *Ostrea couloni, Arca, Cardium*, and *Echinus* as having been collected from "Older Parian strata at Cumaná on the mainland."

Further paleontologic information on the Barranquín formation was given by Hedberg and Pyre (1944, p. 7), who mentioned the occurrence of *Caprina* cf. *C. plumensis* Harris and Hodson and *Amphitriscoelus* cf. *A. waringi* Harris and Hodson at the northwestern end of Caribe Islet north of Barcelona, and in a Barranquín limestone nine kilometers south of Cumaná; *Exogyra*, *Trigonia*, *Cucullaea*, *Arctica*, and *Sphaera* from the upper part of the Barranquín formation on Lobo Islet, near Caribe Islet, and on Chimana Grande Island, north of Guanta; preliminary identifications made by Wells of a collection of corals from the limestones at Las Cinco Ceibas south of Cumaná; and unidentified fossil plants from the islands of Chimana Grande, Picuda Grande, and also from near Cumanacoa.

Wells' description of a coral fauna from the Barranquín limestones at Las Cinco Ceibas and from La Borracha Island north of Barcelona (Wells, 1944) represented the first paleontological paper published on the formation, as well as the first attempt to relate the Barranquín fauna with those of other areas. Wells reported as follows:

Astrocoenia barranquiniensis Wells
Cyathophora hayensis Wells
Cyathophora hedbergi Wells
Stylosmilia gregorii Wells
Stylina sucrensis Wells
Myriophyllia borrachensis Wells
Enallhelia occidentalis Wells
Stylangia laddi Wells
Calamophyllia sandbergeri Felix
Periseris irregularis (Felix)
Meandrophyllia cariacoensis Wells
Meandrophyllia plummeri Wells
Actinaraea arborecens (Felix)
Thecosmilia cumanensis Wells
Ellasmophyllia tolmachoffana (Wells)
Cladophyllia stewartae Wells
Budaia felixi Wells
Stromatopora venezuelensis Wells
Stephanocoenia guadalupae Wells

According to Wells, the Barranquín coral fauna represents a manifestation of the Tethyan "Urgonian" coral facies that existed widely in Europe and Asia during the Neocomian, and later appeared in Mexico (Aptian) and in Texas (Lower Albian, Glen Rose formation). The presence of four Glen Rose species in this fauna, *Cyanthophora hayensis*, *Meandrophyllia plummeri*, *Ellasmophyllia tolmachoffana*, and *Stephanocoenia guadalupae*, and of three Mexican Aptian species *Calomophyllia sandbergi*, *Actinaraea arborecens*, and *Periseris irregularis* (which occurs also in the Glen Rose formation) indicates the affinity of the Barranquín fauna with the North American "Urgonian." However, the major portion of the assemblage which includes new species suggests an even closer affinity with the European Urgonian; the Venezuelan species are closer to European congeners, and several genera are present that are unknown from North America. It is important to note that according to Wells, the closest relative of each of the new species is a Neocomian form, generally of Valanginian or Hauterivian age.

A Lower Cretaceous molluscan fauna from Trinidad recently reported by Cox (1954) should also be mentioned, for it was collected in a horizon equivalent to the Barranquín formation; the limestones of the Cuche formation at Pointe-à-Pierre. This is an assemblage of four gastropod and 20 pelecypod species which bears much similarity to the one collected in the Santa Fé region. Four species are common to both assemblages; *Sphaera corrugata* Sowerby, *Epicyprina angulata* (Sowerby), *Trigonia tocaimaana* Lea, and *Cardita* sp. (the same as *Cardita cumanesa* n. sp. herein). Cox considered the assemblage to be of probable Barremian or Aptian age, as suggested by the presence of a large number of European species that are common in these stages. (Most of these species are also present in the Neocomian stage of Europe.) Perhaps Cox was influenced in assigning a younger age to his assemblage by the occurrence of two species from the Albian of North America, *Neithea bellula* (Cragin) and *Gryphaea* cf. *G. corrugata* Say, for as in the case of Wells' coral fauna, the North American elements in the assemblage are suggestive of a younger age than that indicated by the European elements.

NEW MATERIAL

The material described in this paper was obtained from various localities on the islands to the north of the Bahía de Santa Fé. It was collected from several different limestone horizons of the Barranquín formation in the upper two-thirds of the section exposed at Santa Fé. There are almost 1000

meters of section between the oldest and the youngest fossiliferous horizons. However, no zonation of species was noticed and the same forms that are present in the youngest horizon are found in the oldest fossil bed. The species collected are listed as follows:

Astrocoenia minima, n. sp.
Astrocoenia whitneyi Wells
Stephanocoenia guadalupae Wells
Columastrea antigua (Gerth)
Myriophyllia borrachensis Wells
Myriophyllia cuyleri (Wells)
Isastrea whitneyi Wells
Periseris irregularis (Felix)
Meandrophyllia cariacoensis Wells
Ellasmophyllia tolmachoffana (Wells)
Serpula cretacea (Conrad)
Cidaris sp., spines (two different forms)
Cucullaea recedens Cragin
Gervillia maroma, n. sp.
Exogyra texana weatherfordensis Cragin
Trigonia hondaana Lea
Trigonia tocaimaana Lea
Pholadomya n. sp.
Epicyprina angulata (Sowerby)
Cardita cumanesa, n. sp.
Amphitriscoelus waringi Harris and Hodson
Sphaera corrugata Sowerby
Panope sp.
Calliostoma n. sp.
Angaria keenae, n. sp.
Metriomphalus schwarki, n. sp.
Metriomphalus taguarumensis, n. sp.
Eulima albensis d'Orbigny
Architectonica planorbis (Roemer)
Natica bulimoides (Deshayes)
Prisconatica praelonga (Leymerie)
Lunatia cragini Stanton
Tylostoma n. sp.
Pseudamaura cf. *P. bulbiformis* Sowerby
Turritella ministeri, n. sp.
Turritella pelusae, n. sp.
Turritella seriatim-granulata Roemer
Nerinaea dianae, n. sp.
Nerinaea hicoriensis Craigin
Nerinaea pseudoconvexa Stanton
Nerinaea riverae, n. sp.
Nerinaea roemeri Whitney
Nerinaea trishae, n. sp.
Cerithium krauskopfi, n. sp.
Gymnocerithium lisum, n. sp.
Anchura catedralis, n. sp.
Anchura sucrensis, n. sp.

The holotypes of the new species, as well as all other specimens, are in the collections of the Ministry of Mines and Hydrocarbons, Caracas, Venezuela.

RELATIONSHIPS AND GEOLOGICAL AGE OF THE FAUNA

The fauna of the Barranquín formation shows an admixture of two geographic elements, a North American element consisting of many species known from the Glen Rose formation of Texas and other related formations, and a European element of well known European forms. This admixture of European and North American elements in South American faunas is generally the rule instead of the exception. A difficulty arises, however, when the age of the Barranquín-Cuche fauna is considered; the North American elements are species common in rocks generally held to be of Albian age, while on the other hand, the European element is of Neocomian or possibly Barremian age. This duality in the age of the Barranquín-Cuche fauna has obviously been noticed by previous workers, but having at their disposal collections more limited and less well preserved, they have generally discounted the significance of the minority element, going so far as to doubt their own identifications and qualifying them by using *cf.* and *aff.*, because the species is either too young or too old. This quandary is noticeable also in the general stratigraphic papers on Venezuela and Trindad; European authors, giving more weight to the European element, generally ascribe an older age to the formations than do the North American authors, who think that South American stratigraphy should follow Gulf Coast stratigraphy because of their geographic proximity.

Some workers have attempted to bridge the age difference by placing the Barranquín formation in the Aptian, and have implied a homotaxial relationship, Europe—South America—North America. This age designation is impossible, however, as is more fully discussed in another paper, because the Barranquín underlies the El Cantil formation which contains Lower Aptian ammonites (Rod and Maync, 1954, Collet, 1922). This fact also makes impossible the age correlation of the Barranquín-Cuche and Glen Rose formations. The relationship of these faunas, therefore, must be one of facies.

A facies correlation of the Barranquín and Glen Rose faunas is supported by stratigraphic evidence; both formations represent the sediments laid down during the advance of the warm waters of the Caribbean-Gulf of Mexico sea onto a continental border and both were deposited under similar environmental conditions, as is proved by the pres-

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ence of coral-caprinid reefs in both formations. The Caribbean-Gulf of Mexico basin must have been the center of distribution of the "Urgonian" fauna during the entire Lower Cretaceous, portions of this fauna spreading into Venezuela, Mexico, or Texas during succeeding stages, as the continental borders were transgressed by advancing seas. The North American elements in the Barranquín faunal assemblage must therefore be considered facies fossils and be disqualified when attempting to establish the age of the fauna.

A supposition as to the age of the Barranquín fauna must be based, consequently, solely upon the European element of the assemblage, which has been stated to be most probably Neocomian. Inasmuch as there seems to be no hiatus between the Barranquín and the overlying Lower Aptian El Cantil formation, the Barranquín formation probably also represents the Barremian in eastern Venezuela.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA Ehrenberg
Subclass HEXACORALLIA Haeckel
Order SCLERACTINIA Bourne
Suborder ASTROCOENIIDA Wells
Family ASTROCOENIIDAE Koby
Subfamily ASTROCOENIINAE Koby
Genus ASTROCOENIA Milne-Edwards and Haime, 1848

Astrocoenia Milne-Edwards and Haime, 1848, C. R. Acad. Sci. (Paris), v. 27, p. 469. Type species: *Astrea numisma* Defrance, 1828, by monotypy.

ASTROCOENIA MINIMA von der Osten, n. sp.
Pl. 63, fig. 13

Corallum small, massive, irregular in shape, with knobby protuberances, forming undulating calicular surface; calices small, polygonal, shallow, .8–1 mm. in diameter from wall to wall; corallite walls thin, directly fused, upper edges forming a thin ridge; 16 septa, eight thick, reaching columella, other eight thinner, short, reaching less than half-way to columella; columella small, styliform; dissepiments present.

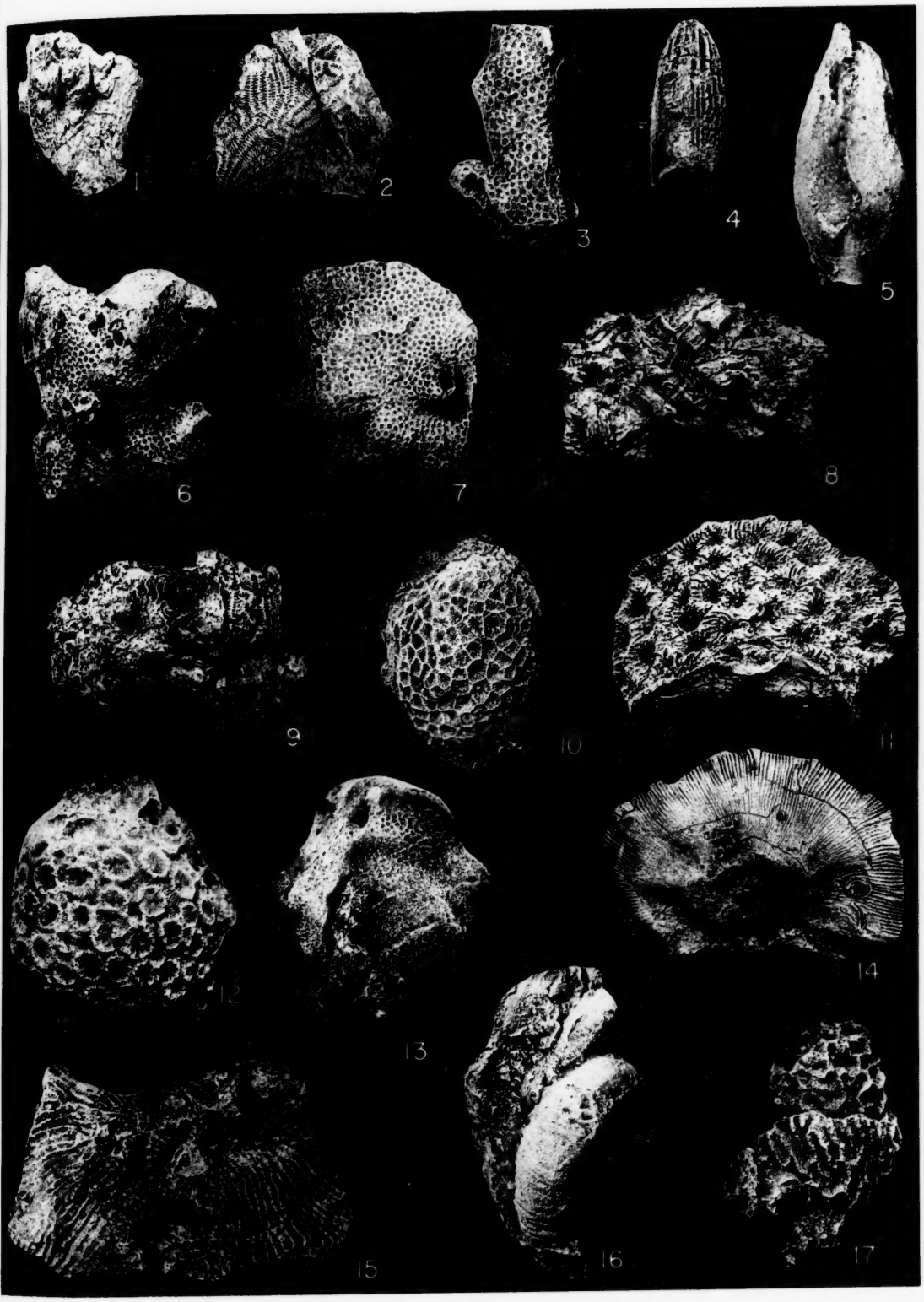
Holotype.—A small corallum collected from the Picuda member of the Barranquín formation at MMH locality Su 123.

Dimensions.—Corallum 42×27×28 mm.

Discussion.—The octameral septal arrangement of this species distinguishes it from most other American Cretaceous species of *Astrocoenia*, for only two, *A. maloniana* and *A. pattoni* have an octameral arrangement. The species is distinguished from the former by the small size of the calices, and from the latter, which is quite similar in other respects, by the close proximity of the calices, even in the worn condition. Those of *A. pattoni* are separated by a distance almost equal to their diameter.

EXPLANATION OF PLATE 63

FIG. *1*—*Elasmophyllia tolmachoffana* (Wells), ×0.6.
2—*Myriophyllia borrachensis* Wells, ×0.58.
3—*Columastrea antigua* (Gerth), ×0.69.
4—*Cidaris* sp., ×2.5.
5—*Cidaris* sp. aff. *C. californicus* Clark, ×2.
6—*Astrocoenia whitneyi* Wells, ×0.5, globose form.
7—*Astrocoenia whitneyi* Wells, ×0.67, flattened form.
8—*Elasmophyllia tolmachoffana* (Wells), ×0.52.
9—*Myriophyllia borrachensis* Wells, ×0.54.
10—*Isastrea whitneyi* Wells, ×0.69.
11—*Periseris irregularis* (Felix), ×1.14, front view of corallum.
12—*Stephanocoenia guadalupae* Wells, ×1.
13—*Astrocoenia minima*, n. sp., ×1.
14—*Periseris irregularis* (Felix), ×1.3, rear view of corallum.
15—*Myriophyllia cuyleri* (Wells), ×0.48.
16—*Serpula cretacea* (Conrad), ×1.25.
17—*Meandrophyllia cariacoensis* Wells, ×0.63.



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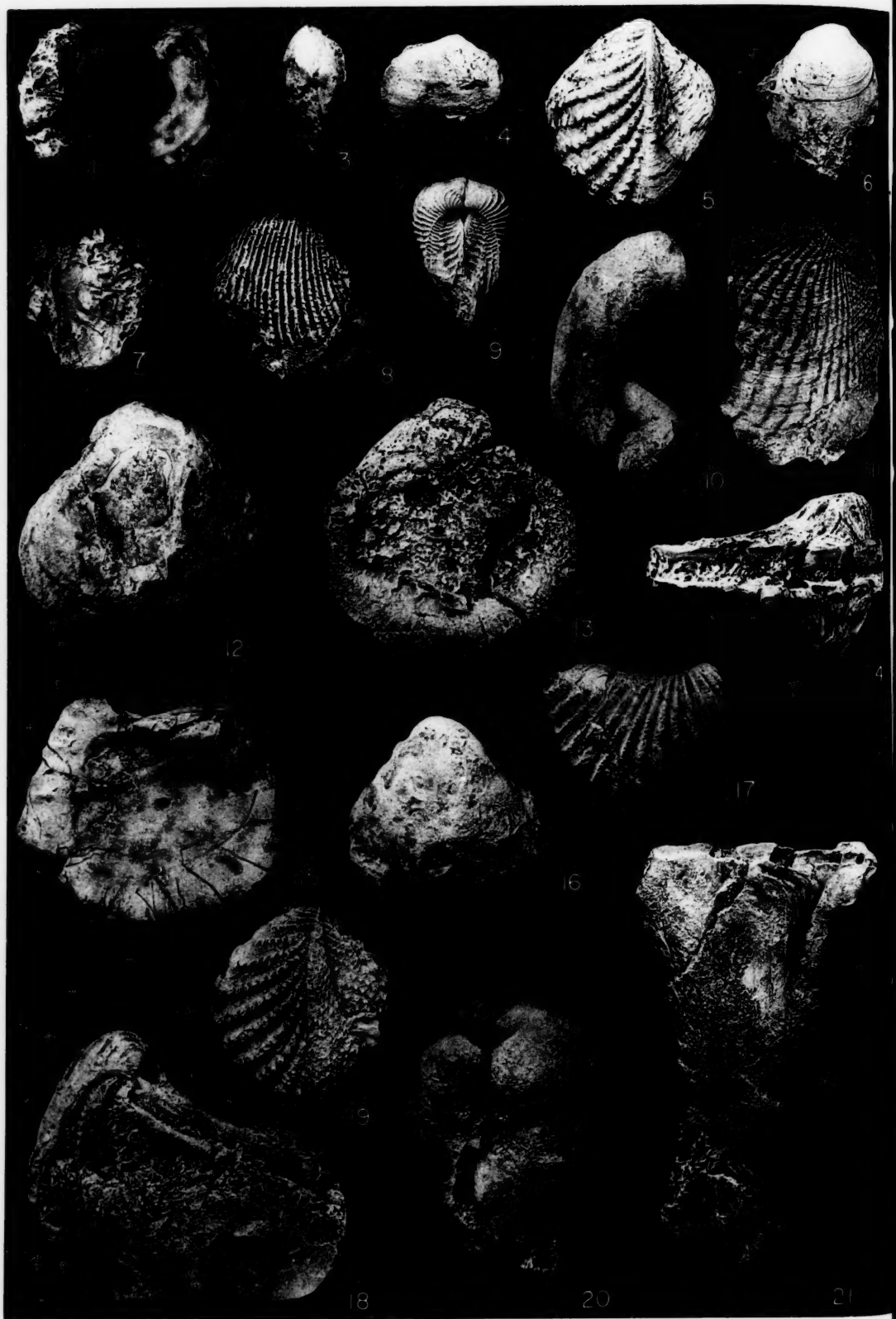
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ASTROCOENIA WHITNEYI Wells, 1932
Pl. 63, figs. 6,7

Astrocoenia whitneyi Wells, 1932, Jour. Paleontology, v. 6, p. 230, pl. 31, fig. 6; pl. 32, fig. 1,2; pl. 37, fig. 1.

Two forms of this species are described by Wells from the Glen Rose formation of Texas, one making tall masses rounded at the top and tapering towards the base, the other making broad, flattened masses, with clusters of corallites forming knoblike protuberances on the surface. Both types are recognized among the specimens collected at Santa Fé.

Occurrence.—The specimens were collected from the Morro Blanco member of the Barranquín formation, at MMH locality Su 124.

Genus STEPHANOCOENIA Milne-Edwards and Haime, 1848

Stephanocoenia Milne-Edwards and Haime, 1848, C. R. Acad. Sci. (Paris), v. 27, p. 469. Type species: *Astrea intersepta* Lamarck, 1816, (non *Madrepora intersepta* Esper, 1797) =*S. michelini* Milne-Edwards and Haime, 1848, by monotypy.

STEPHANOCOENIA GUADALUPAE Wells, 1932
Pl. 63, fig. 12

Stephanocoenia (?) *guadalupae* Wells, 1932, Jour. Paleontology, v. 6, p. 235, pl. 32, fig. 8,9; pl. 39, fig. 3.

Stephanocoenia guadalupae Wells, Jour. Paleontology, v. 18, p. 433, pl. 69, fig. 3,4, 1944.

The type of this species is from the lower Glen Rose formation of Texas; it was later reported from the Barranquín formation at La Borracha Island, 40 kilometers west of Santa Fé.

Occurrence.—The single corallum was found near the middle of the Taguarumo member of the Barranquín formation, at MMH locality Su 157.

Genus COLUMASTRAEA d'Orbigny, 1849

Columastraea d'Orbigny, 1849, Note Polyp. Foss, p. 9. Type species: *Astrea striata* Goldfuss, 1827, by monotypy.
Columnastrea d'Orbigny, 1849 (variant spelling).

COLUMASTRAEA ANTIGUA (Gerth), 1928
Pl. 63, fig. 3

Columnastrea antigua Gerth, 1928, Leidsche Geolog. Mededeelingen, v. 3, pt. 1, p. 5, pl. 1, fig. 4,4a.
——, Weaver, Mem. Univ. Washington, v. 1, p. 165, pl. 11, fig. 10,11, 1931.

The type of this species was collected by Weaver in Argentina and sent to Gerth for study. According to Weaver (1931), it is comon in the upper part of the Agrio formation, of Aptian age, at Vaca Muerta, west-central Argentina.

Occurrence.—Specimens were found in the Morro Blanco member of the Barranquín

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EXPLANATION OF PLATE 64

FIG. *1*—*Exogyra texana weatherfordensis* Cragin, ×0.48, external view.
2—*Exogyra texana weatherfordensis* Cragin, ×0.48, internal view.
3—*Panope* sp., ×0.43, dorsal view.
4—*Panope*, sp. ×0.47, right valve.
5—*Trigonia hondaana* Lea, 0.37, exterior view of right valve.
6—*Epicyprina angulata* (Sowerby), ×0.45, right valve.
7—*Exogyra texana weatherfordensis* Cragin, ×0.53.
8—*Cardita cumanesa*, n. sp., ×1.3.
9—*Trigonia tocaimaana* Lea, ×0.63, dorsal view.
10—*Amphitriscoelus waringi* Harris and Hodson, ×0.61.
11—*Pholadomya* n. sp., ×1.2, fragment of left valve.
12—*Sphaera corrugata* Sowerby, ×0.68, exterior view of left valve.
13—*Sphaera corrugata* Sowerby, ×0.68, internal view of left valve.
14—*Gervillia maroma* n. sp. ×0.5, dorsal view.
15—*Trigonia hondaana* Lea, ×0.42, internal view of left valve.
16—*Cucullaea recedens* Cragin, ×0.4, left valve.
17—*Trigonia tocaimaana* Lea, ×0.5, right valve.
18—*Trigonia tocaimaana* Lea, ×0.93, internal view of right valve.
19—*Trigonia hondaana* Lea, ×0.4, variation in ornamentation of right valve.
20—*Cucullaea recedens* Cragin, ×4.4, dorsal view of another specimen.
21—*Gerillia maroma*, n. sp., ×0.5, right valve.

formation, at MMH localities Su 124 and Su 126.

Family STYLINIDAE d'Orbigny
Subfamily STYLININAE Verrill
Genus MYRIOPHYLLIA d'Orbigny, 1849

Myriophyllia d'Orbigny, 1849, Note Polyp. Foss., p. 8. Type species: *Meandrina rastellina* Michelin, 1843, by monotypy.
non *Myriophyllia* Volz, 1849, Paleontogr., v. 43, n. 1, 2.

MYRIOPHYLLIA BORRACHENSIS Wells, 1944
Pl. 63, fig. 2,9

Myriophyllia borrachensis Wells, 1944, Jour. Paleontology, v. 18, p. 436, pl. 70, fig. 2,3.

This species has been described from the Chimana formation of La Borracha Island, 40 kilometers west of Santa Fé, and from the Barranquín limestones at Las Cinco Ceibas, about 10 kilometers south of Cumaná, on the Cumanacoa road.

Other American Lower Cretaceous species of *Myriophyllia* are known from the Barremian and Aptian of Mexico and from the lower Glen Rose formation and the Edwards limestone of central Texas.

Occurrence.—Specimens were collected from both the Morro Blanco and Picuda members of the Barranquín formation. The MMH localities were Su 124 and Su 146.

MYRIOPHYLLIA CUYLERI (Wells), 1932
Pl. 63, fig. 15

Eugyra cuyleri Wells, 1932, Jour. Paleontology, v. 6, p. 237, pl. 35, fig. 4.

Myriophyllia cuyleri is very close to *M. borrachensis* both in width of the series and separation of the septa. In the latter species however, the septa are alternating rather than equal as in the former. The single large corallum found in the Santa Fé area has predominantly alternating septa, although these tend to be equal on some parts of the corallum.

Wells' type material is from the lower Glen Rose formation of Texas. The species was originally placed in the genus *Eugyra* de Fromentel, 1857, but this genus has been included in *Myriophyllia* in Vaughan and Wells' revision of the Scleractina.

Occurence.—The specimen is from the Picuda member of the Barranquín formation, collected at MMH locality Su 147.

Suborder FUNGIIDA Duncan
Superfamily AGARICIOIDAE Vaughan and Wells
Family CALAMOPHYLLIIDAE Vaughan and Wells
Genus ISASTREA Milne-Edwards and Haime, 1851

Isastrea Milne-Edwards and Haime, 1851, Arch. Mus. Paris, v. 5, p. 102. Type species: *Astrea helianthoides* Goldfuss, 1827, by subsequent designation of Quenstedt, 1857, (*fide* Vaughan and Wells).

ISASTREA WHITNEYI Wells, 1932
Pl. 63, fig. 10

Isastrea whitneyi Wells, 1932, Jour. Paleontology, v. 6, p. 245, pl. 39, fig. 4,5.

According to Wells, *Isastrea whitneyi* closely resembles *I. serialis* from the upper Dogger of Monte Pastello, near Verona, and is very common at several localities in the lower Glen Rose of Texas, from where the species was originally described.

Occurrence.—The specimen was found in the Taguarumo member of the Barranquín formation, at MMH locality Su 92.

Genus PERISERIS Ferry, 1870

Periseris Ferry, 1870, Ann. Acad. Macon, v. 9, p. 189. Type species: *Agaricia elegantura* d'Orbigny, 1850, by monotypy.

PERISERIS IRREGULARIS (Felix), 1891
Pl. 63, fig. 11,14

Siderofungia irregularis Felix, 1891, Paleontogr., v. 37, p. 151, pl. 22, fig. 12,12a.
——, Wells, Jour. Paleontology, v. 6, p. 250, pl. 35, fig. 3; pl. 39, fig. 2, 1932.
Periseris irregularis (Felix). Wells, Jour. Paleontology, v. 18, p. 439, pl. 71, fig. 4, 1944.

The material described by Felix was from the Upper Aptian of the Tehuacan region of Mexico. Wells reported the species in the Glen Rose formation of Texas and in the Barranquín formation of Venezuela, from the limestones at Las Cinco Ceibas, State of Sucre.

Occurrence. Both specimens collected were found in the Morro Blanco member of the Barranquín formation, at MMH locality Su 124.

Superfamily PORITOIDAE Vaughan and Wells
Family MICROSOLENIDAE Koby
Genus MEANDROPHYLLIA d'Orbigny, 1849

Meandrophyllia d'Orbigny, 1849, Note Polyp. Foss., p. 9. Type species: *Meandrina lotharinga* Michelin, 1843, by monotypy.

MEANDROPHYLLIA CARIACOENSIS Wells, 1944
Pl. 63, fig. 17

Meandrophyllia cariacoensis Wells, 1944, Jour. Paleontology, v. 18, p. 440, pl. 71, fig. 8,9.

The single corallum collected in the Santa Fé region seems to have developed on a gastropod shell, probably *Pseudamaura*, that has disappeared.

Well's type is from the Barranquín formation at Las Cinco Ceibas, about 10 kilometers south of Cumaná on the Cumanacoa road.

Occurrence.—The specimen was found in the Morro Blanco member of the Barranquín formation, at MMH locality Su 216.

Suborder FAVIIDA Vaughan and Wells
Family MONTLIVAULTIIDAE Dietrich
Subfamily LASMOGYRINAE Vaughan and Wells
Genus ELASMOPHYLLIA d'Achiardi, 1875

Elasmophyllia d'Achiardi, 1875, Cor. Eoc. Friuli, 28. Type species: *Elasmophyllia gigantea* d'Achiardi, 1875, by monotypy.

ELASMOPHYLLIA TOLMACHOFFANA (Wells), 1932
Pl. 63, fig. 1,8

Aplosmilia ? tolmachoffana Wells, 1932, Jour. Paleontology, v. 6, p. 234, pl. 30, fig. 2; pl. 31, fig. 2.
Elasmophyllia tolmachoffana (Wells). Wells, Jour. Paleontology, v. 18, p. 442, pl. 72, fig. 6,8, 1944.

The specimens that represent the species in this collection are remarkably well preserved.

The species was described by Wells from material collected in the Glen Rose formation of Texas. Due to imperfect material he placed the species in the genus *Aplosmilia*, but later revised this allocation when he obtained better specimens from the Barranquín formation, from the limestones at Las Cinco Ceibas, State of Sucre.

Occurrence.—Specimens were collected from the Picuda and Morro Blanco members of the Barranquín formation, at MMH localities Su 146 and Su 124, respectively.

Phylum ANNELIDA
Class CHAETOPODA
Subclass POLYCHAETA
Order TUBICOLA
Family SERPULIDAE Burmeister
Subfamily SERPULINAE, s.s.
Genus SERPULA Linnaeus, 1758

Serpula Linnaeus, 1758, Syst. Nat., p. 786. Type species: *Serpula contortuplicata* Linnaeus, 1758, by subsequent designation of Montfort, 1810, Conchy. Syst., p. 27.

SERPULA CRETACEA (Conrad), 1875
Pl. 63, fig. 16

Diploconcha cretacea Conrad, 1875, Geol. Survey North Carolina Rept., v. 1, App. A, p. 12, pl. 2, fig. 26.
Serpula whitfieldi Weller, 1907. Geol. Survey New Jersey, Paleontology, v. 4, p. 308, pl. 19, fig. 2.
Serpula cretacea (Conrad). Stephenson, North Carolina Geol. Econ. Survey, v. 5, p. 67, pl. 9, fig. 1–12, 1923.
——, Stephenson, Univ. Texas Pub., no. 4101, pl. 4, fig. 1–3, 1941.

Two curved tubes, approximately 4 cm. long, broken off at both ends, represent this species in the material collected in the Santa Fé area. The tubes are cemented together, and to a fragment of *Gervillia*, but their position suggests they represent two different individuals. At the broken ends, the tubes measure 7 and 9 mm. and 5 and 7 mm. in diameter. The walls are approximately 1.5 mm. thick. The outside surface is covered by fine growth lines that tend to become undulating, as described by Conrad and by Stephenson for this species. Conrad's original description is brief and mentions two tubes as the two halves of a mollusk. Stephenson, however, gives full descriptions and has several illustrations in the two papers listed above, with which the Santa Fé specimens were compared. His figures 1, 3, and 5 of plate 9, showing specimens from Snow Hill, North Carolina, are particularly close to the Venezuelan specimens.

The species has a wide distribution in the Cretaceous of the Atlantic Coast states, and is known as far west as Texas.

Occurrence.—The specimens were collected at the base of the Taguarumo member of the Barranquín formation at MMH locality Su 90.

Phylum ECHINODERMATA
Class ECHINOIDEA Bronn
Order CIDAROIDA Duncan
Family CIDARIDAE Gray
Subfamily STEROCIDARINAE Lambert
Group CIDARINA Mortensen
Genus CIDARIS Leske, 1778

Cidaris Leske, 1778, Add. Klein Nat. Disp. Echin., v. 17, p. 74. Type species: *Echinus cidaris* Linnaeus, 1758, =*Dorocidaris papillata* (Leske), by absolute tautonomy.

CIDARIS sp. aff. C. CALIFORNICUS Clark, 1863

Pl. 63, fig. 5

Cidaris californicus Clark, 1893, U. S. Geol. Survey Bull. 97, p. 36, pl. 6, fig. 1a,1b.

Several well preserved club-shaped spines were collected in the Santa Fé area which do not seem to fit any of the described species. They are almost spherical-ellipsoids (resembling American footballs), above a very narrow neck which was not preserved. A typical spine is 21 mm. long from the tip to the beginning of the neck, where it is broken off. Its width is greatest at about the middle —11 mm.—tapering convexly upwards to the tip and downwards to the neck, which is 3 mm. wide. The surface is covered with granules small and round near the base, growing coarser and longitudinal toward the point. Some granules are aligned longitudinally.

The spines have some similarity to those figured by Clark from the Jurassic of California, which he describes as *C. californicus.* However, these spines are larger, seen to have the granules of a different shape, and have a wider neck. They are also similar to some spines of Cretaceous age from Mexico now in the Palmer collection at Stanford University labeled *C. dixoni* Cotteau; these seem to be misidentified, for they differ quite markedly from Cotteau's figures (in d'Orbigny, 1842, v. 7, pl. 1051). The ornamentation of these Mexican spines is very similar to that of the Santa Fé spines, and they show the same narrow necks, but they are almost twice as large.

Occurrence.—The spines were collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 132.

CIDARIS sp.
Pl. 63, fig. 4

Cidaris sp., Adkins and Winton, 1919; Univ. Texas Bull., no. 1945, p. 50, pl. 9, fig. 5.

The broken point of a cidarid spine 10 mm. long was found in the Santa Fé area adhering to a fragment of limestone. The spine is marked by fine longitudinal striations averaging three or four in 1 mm., coarser toward the point. The broken end has a diameter of 4.5 mm.

The specimen is very similar to Adkins and Winton's figure 5 of cidarid spines found in the Quarry limestone group of Gainesville, Texas.

Occurrence.—The spine was collected from the Morro Blanco member of the Barranquín formation, at MMH locality Su 216.

Phylum MOLLUSCA
Class PELECYPODA Goldfuss
Order PRINODESMACEA Dall
Section TAXODONTA Neumayr
Superfamily ARCACEA Deshayes
Family PARALLELODONTIDAE Dall
Genus CUCULLAEA Lamarck, 1801

Cucullaea Lamarck, 1801, Syst. Anim., p. 116. Type species: *Cucullaea auriculifera* Lamarck, 1801 =*Arca cucullata* Röding, 1798 =*Arca cucullus* Gmelin, 1791, by subsequent designation of Children, 1823, Quart. Jour. Sci., p. 318.

CUCULLAEA RECEDENS Cragin, 1894
Pl. 64, fig. 16,20

Cucullaea terminalis Conrad var. nov. *recedens* Cragin, 1894, Amer. Geol., v. 14, p. 3, pl. 1, fig. 19.

Cucullaea recedens Cragin. Twenhofel, Geol. Survey Kansas, Bull. 9, p. 66, pl. 15, fig. 14; pl. 16, fig. 1–3; pl. 17, fig. 3,4, 1924.

This species is represented in the Santa Fé material by two specimens: an internal mold slightly deformed by a clock-wise rotation of one valve with respect to the other, and an obliquely crushed, but otherwise well preserved pair of valves, with beaks and hinge-area intact, and the concentric growth-lines, which constitute the only surface ornamentation, clearly discernible.

In both specimens the beaks lie one-fourth the length of the shell from the anterior margin as described by Cragin and by Twenhofel. They thus differ from *Cucullaea*

terminalis, which has the beaks more anteriorly placed.

Occurrence.—The specimens were collected in the Taguarumo member of the Barranquín formation, at MMH locality Su 109.

Section SCHIZODONTA Steinmann
Superfamily PTERIACEA Dall
Family ISOGNOMONIDAE Zittel
Genus GERVILLIA Defrance, 1820

Gervillia Defrance, 1820, Dict. Sci. Nat., v. 18, p. 502. Type species: *Gervillia solenoidea* Defrance, 1820, by monotypy.

GERVILLIA MAROMA von der Osten, n. sp.
Pl. 64, fig. 14,21

Shell large, pyriform with alate posterior border; sculpture consisting of about 15 spinose rounded ribs, on umbos only; well defined, laminated growth-lines on rest of shell; ribs high and narrow, with large, wedge-shaped spines where crossed by growth-lines; intercostal spaces about three times as wide as ribs; beaks prominent, nearly terminal, directed strongly inward and forward; anterior and posterior margins straight, joining at an angle of 90°, just forward of beaks; hinge strong, with four vertical cartilage pits; first pit very small, V-shaped, directly under beak; second pit, long and narrow; third pit about twice as broad as second; fourth pit intermediate; dentition (in paratype) consisting of long, slightly curved, undefined dental ridges; muscle scars not visible in holotype or paratype.

Holotype.—Individual with both valves, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 109.

Paratype.—A right valve, showing the dentition, collected at the same locality as the holotype.

Dimensions.—Height 168 mm., length 114 mm., depth of both valves together 54 mm.

Discussion.—This species bears some resemblance to *Gervillia alaeformis* Sowerby, especially in size, and may have been mistaken for it by some workers. This could easily happen with imperfect material such as fragments or transverse sections in limestone. The two species are differentiated, however, by the surface sculpture and by a much larger alate posterior border in *G. alaeformis*, giving it an almost square outline.

Superfamily OSTRAECEA Goldfuss
Family OSTREIDAE Lamarck
Genus EXOGYRA Say, 1820

Exogyra Say, 1820, Amer. Jour. Sci., v. 2, (1), p. 43. Type species: *Exogyra costata* Say, 1820, by monotypy.

EXOGYRA TEXANA WEATHERFORDENSIS Cragin, 1893
Pl. 64, fig. 1,2,7

Exogyra weatherfordensis Cragin, 1893, Geol. Survey Texas, 4th Ann. Rept., p. 188, pl. 45, fig. 7–10.
Exogyra texana Roemer var. *weatherfordensis* Cragin. Hill and Vaughan, U. S. Geol. Surv., Bull. 151, p. 30, 1898.
Exogyra texana weatherfordensis Cragin. Stanton, U. S. Geol. Survey Prof. Paper 211, p. 38, pl. 30, fig. 3–12, 1947.

This species is represented by two fairly well preserved specimens, both left valves. One specimen, (pl. 2, fig. 1), has the posterior border missing, which gives it a "lunate" appearance. Enough surface of the posterior slope is present, however, to show the fine subradiate plications described for this form by Cragin. The anterior border is well preserved and has the twelve strong, oblique, subtubercular plications on the outside surface and the feeble milling of the inside border mentioned by Cragin. Although this specimen can be compared with Cragin's rather poor illustrations, a better figure is given by Roemer (1852, pl. 10, fig. 1a,1e), as *Exogyra texana*.

The second specimen (pl. 2, fig. 7) has the posterior border intact but is lacking part of the upper border, including part of the beak. The plications on both the anterior and posterior slopes can be observed, however, conforming to Cragin's description. This specimen can best be compared with Cragin's figure 9 and Stanton's figure 11.

The species is known to occur principally in the Glen Rose formation of Texas.

Occurrence.—The specimens are both from near the base of the Taguarumo member of the Barranquín formation, at MMH localities Su 90 and Su 92.

Superfamily TRIGONIACEA Bronn
Family TRIGONIIDAE Lamarck
Genus TRIGONIA Bruguière, 1789

Trigonia Bruguière, 1789, Ency. Meth., (Vers), v. 1, p. 14. Type species: *Venus sulcata* Hermann, 1781, under suspension of the rules by the International Commission on Zoological Nomenclature (Opinion 327, 1955).

TRIGONIA HONDAANA Lea, 1840
Pl. 64, fig. 5,15,19

Trigonia hondaana Lea, 1840, Trans. Amer. Philos. Soc., (2), v. 7, p. 256, pl. 8, fig. 9.

This species is very common in the Barranquín rocks of the Santa Fé area where several well preserved specimens were collected. It is well known from the Lower Cretaceous of South America and southwestern Europe and is common in the Aptian of Columbia, Peru, Equador, Spain, Portugal, and Algeria. However, to the writer's knowledge, it has not been reported previously from Venezuela.

Occurrence.—The species is common in the "Trigonia Beds" of the Taguarumo member of the Barranquín formation and is also found in the Morro Blanco member of the formation. Specimens were collected at MMH localities Su 110 and Su 177.

TRIGONIA TOCAIMAANA Lea, 1840
Pl. 64, fig. 9,17,18

Trigonia tocaimaana Lea, 1840, Trans. Amer. Philos. Soc., (2), v. 7, p. 256, pl. 9, fig. 8. Type: near Tocaima, Colombia.
Trigonia subcrenulata d'Orbigny, 1842, Coq. et Echin. Foss. de Colombie, Paris, p. 52, pl. 19, fig. 7–9. Type: Colombia.

This is one of the most common species found in the Santa Fé area. It is especially abundant in a red calcareous siltstone shell-bed, located at about the middle of the Taguarumo member of Barranquín formation, 40% of which is composed of broken and whole shells of this species.

The species has a wide distribution in the Lower Cretaceous of South America. It has been reported from the Aptian of Colombia, the Neocomian of Brazil and Chile, and the Aptian-Albian of Peru and Venezuela (Barranquín, El Cantil, and Chimana formations). It is to be noted that the name *Trigonia subcrenulata* d'Orbigny is more often applied to this species in the literature than its correct name, *T. tocaimaana* Lea, which has priority by two years.

Occurrence.—The species is the most common form in the "Trigonia Beds" of the Taguarumo member of the Barranquín formation. It is also abundant in the Morro Blanco member of the formation. Localities of the MMH are at Su 110, Su 124, Su 130, Su 132, Su 177 and Su 217.

Order ANOMALODESMACEA Dall
Superfamily ANATINACEA Dall
Family PHOLADOMYACIDAE Gray
Genus PHOLADOMYA Sowerby, 1823

Pholadomya Sowerby, 1823, Gen. Shells, pt. 19, pl. 6. Type species: *Pholadomya candida* Sowerby, by subsequent designation of Gray, 1847, Genera Rec. Moll., p. 194.

PHOLADOMYA n. sp.
Pl. 64, fig. 11

Shell large; sculpture consisting of many, wide, rounded ribs, irregular in size and direction, undulating slightly; interspaces much narrower than ribs; crossed by fine, well defined growth-lines, some stronger than others, forming concentric ridges and valleys; valve only slightly convex, umbos not pronounced; shell with strong prismatic layer; borders, beaks and dentition unavailable in the figured specimen.

Figured specimen.—A fragment of the left valve, including the umbonal area, but not the beak, collected from the Morro Blanco member of the Barranquín formation, at MMH locality Su 125.

Dimensions.—The fragment is 23×34 mm., the curvature producing a depth of 6 mm.

Discussion.—The specimen is too fragmentary to warrant a specific name, although no shell with this ornamentation is known. The small curvature of the fragment, which corresponds to the region of maximum convexity of a shell, is rare for the genus, but this may be due to compression. The strong prismatic layer of the shell, the irregularity of the ribbing, and the general shape of the shell as suggested by the growth-lines, were the criteria for the generic allocation.

Order TELEODESMACEA Dall
Section DIOGENODONTA Zittel
Superfamily TRAPEZIACEA Dall
Family PLEUROPHORIDAE Dall
Genus EPICYPRINA Casey, 1952

Epicyprina Casey, 1952, Malac. Soc. London, Proc., v. 29, p. 154. Type species: *Venus angulata* Sowerby, 1814, by original designation.

EPICYPRINA ANGULATA (Sowerby), 1814
Pl. 64, fig. 6

Venus angulata Sowerby, 1814, Min. Conch., v. 1, p. 145, pl. 65.
Cyprina (*Venilicardia*) *angulata* (Sowerby). Woods, Cret. Lam. England: Paleontogr. Soc., v. 61, p. 141, pl. 22, fig. 1–4, 1907.
Cyprina angulata (Sowerby). Weaver, Mem. Univ. Washington, v. 1, p. 325, 1931.
Epicyprina angulata (Sowerby). Casey, Malac. Soc. London, Proc., v. 29, p. 154, pl. 7, fig. 2; pl. 8, fig. 1; text-fig. 72,73, 1952.
——, Cox, Jour. Paleontology, v. 28, p. 633, pl. 66, fig. 4, 1954.

A single right valve was referred to this species. The valve is somewhat smaller than the one described by Cox, but almost three times the size of Weaver's Argentine specimen. It is slightly larger than a comparable specimen from Colombia, which Dietrich figures as *Cyprina* (*Venilicardia*) sp. (Dietrich, 1938, p. 103, pl. 21, fig. 3).

The species is common in the Aptian of England and France, and has a wide distribution in the Neocomian and the Barremian of South America.

Occurrence.—The specimen was collected in the Taguarumo member of the Barranquín formation, at MMH locality Su 177.

Superfamily CARDITACEA Menke
Family CARDITIDAE Gill
Geneus CARDITA Bruguière, 1792

Cardita Bruguière, 1792, Ency. Meth., (Vers), v. 1, p. 401. Type species: *Chama antiquata* Linnaeus, 1758 = *Cardita sulcata* Bruguière, 1792, by subsequent designation of Children, 1823, Quart. Jour. Sci., p. 316.

CARDITA CUMANESA von der Osten, n. sp.
Pl. 64, fig. 8

Shell small, subquadrate; sculpture consisting of 32 serrate, radial ribs, of which 22 extend from the beak to the ventral border, the other ten ornamenting the anterior and posterior margins; ribs high and narrow, with minute spines set close together, giving them a serrate appearance; intercostal spaces about twice as wide as ribs; beak prominent, nearly terminal, directed strongly forward; anterior and posterior margins nearly straight, joining at an angle of about 80°; ventral border crenulated by the ends of the radial ribs; hinge of the right valve strong, dentition eroded; in holotype interior of this valve and left valve not available.

Holotype.—A right valve, collected from the Taguarumo member of the Barranquín formation at MMH locality Su 110.

Dimensions.—Height 19 mm., length 21 mm., depth (of one valve) 9 mm.

Discussion.—The species is similar to *Cardita belviderense* Cragin, from the Kiowa member of the Belvidere formation of Kansas, but it is distinguished by its smaller size, the form of the beak, and the more numerous and narrower ribs.

C. cumanesa is the *Cardita* sp. which Cox recorded from Pointe-à-Pierre in Trinidad, (Cox, 1954), found in approximately the same geological horizon. It is also the form which Dietrich (1938) cited from Colombia as *Cardita* sp. cf. *C. neocomiense* d'Orbigny.

Superfamily CHAMACEA Geinitz
Family CAPRINIDAE d'Orbigny
Genus AMPHITRISCOELUS Harris and Hodson, 1922

Amphitriscoelus Harris and Hodson, 1922, Paleontogr. Americana, v. 1, n. 3, p. 12. Type species: *Amphitriscoelus waringi* Harris and Hodson, 1922, by monotypy.

AMPHITRISCOELUS WARINGI Harris and Hodson, 1922
Pl. 64, fig. 10

Amphitriscoelus waringi Harris and Hodson, 1922, Paleontogr. Americana, v. 1, n. 3, p. 12, pl. 1–4.

This species was described by Harris and Hodson from a limestone bed in Trinidad that, according to these authors, is likely to represent a Cenomanian horizon, but "may well be as low as the Aptian," (p. 15). The species has also been reported from Venezuela, in the Barranquín formation at Caribe Islet, just north of La Borracha Island, and at Las Cinco Ceibas, ten kilometers south of Cumaná.

Occurrence.—The specimen is from the

Taguarumo member of the Barranquín formation, at MMH locality Su 92.

Superfamily LUCINACEA Anton
Family CORBIDAE Dall
Genus SPHAERA Sowerby, 1822

Sphaera Sowerby, 1822, Min. Conch., v. 4, p. 41. Type species: *Sphaera corrugate* Sowerby, 1822, by monotypy.

SPHAERA CORRUGATA Sowerby, 1822
Pl. 64, fig. 12,13

Sphaera corrugata Sowerby, 1822, Min. Conch., v. 4, p. 42, pl. 335 (marked 334).
——, Woods, Cret. Lam. England, Paleontogr. Soc., v. 61, p. 157, pl. 24, fig. 24; pl. 25, fig. 1,2, 1907.
Corbis (*Sphaera*) *corrugata* (Sowerby). Dietrich, Est. Geol. Paleont., Cordillera Orient. Columbia, p. 102, pl. 21, fig. 1a,1b, 1938.
Sphaera corrugata Sowerby. Cox, Jour. Paleontology, v. 28, p. 633, pl. 65, fig. 7, 1954.

A fairly well preserved left valve is the only representative of this species in the material collected in the Santa Fé region. The specimen compares in every way with the description and figure of a right valve given by Cox, his specimen having been collected by Kugler in the Remanié Bed of Trinidad, and there is no doubt that they represent the same species. This is also the case with the specimen reported by Dietrich from Colombia.

There is, however, a problem as to the relationship of the South American specimens with the English forms described and illustrated by Sowerby and by Woods. Although the South American specimens are similar in form of shell and ornamentation, they are smaller in size and less convex than the English. They resemble more in size the species *Sphaera americana*, described by Imlay from the Neocomian of northern Mexico, which also has a similar ornamentation, as Cox pointed out (*op. cit.*, p. 633), but it is different in form.

In the writer's opinion, the South American forms should remain in the species *S. corrugata*, and be regarded as a variety, smaller in size than the European members of the species.

Occurrence.—The specimen was collected at the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Section TELEODONTA Zittel
Superfamily MYACEA Menke
Family HIATELLIDAE Kuroda, 1935
Genus PANOPE Ménard, 1807

Panope Ménard, 1807, Mém. sur un Nouv. Gen. de Coq. bivalve-equivale de la famille des Solenoides, 37 p., (Jan.). Type species: *Mya glycymeris* Born, 1780, by monotypy.
Panopea Ménard, 1807, Ann. Mus. Hist. Nat., v. 9, p. 131, (April), (variant spelling).
Panopeae Lamarck, 1818, Hist. Nat. Anim. s. vert., v. 5, p. 456.

PANOPE sp.
Pl. 64, fig. 3,4

Four badly worn internal molds were referred to this genus, due to their similarity of form, size, and nature of the umbonal region with pictures of *Panope neocomiensis* (Leymerie) figured by Weaver (1931, pl. 41, fig. 268–270). Although there is a difference between Weaver's and d'Orbigny's illustrations of this species, (d'Orbigny, 1845, pl. 353, fig. 3–8), especially in the position of the umbos, which appear to be more posterior in the Argentine specimens than in the French, these are within the range of variation reported by Weaver for the species. The position of the umbos in the Santa Fé specimens, however, is identical to that shown in Weaver's illustrations.

The species *P. neocomiensis* is common in the Agrio formation of Argentina, which has several species in common with the Barranquín formation at Santa Fé. It is also known from the Lower Cretaceous of France and Switzerland.

Occurrence.—All four specimens were collected in the Taguarumo member of the Barranquín formation, at MMH locality Su 109.

Class GASTROPODA Cuvier
Subclass STREPTONEURA Spengel
Order ASPIDOBRANCHIA Scheigger
Suborder RHIPIDOGLOSSA Troschel
Family TROCHIDAE Fleming
Subfamily TROCHINAE, s.s.
Genus CALLIOSTOMA Swainson, 1840

Calliostoma Swainson, 1840, Treat. Malac., p. 218 and 351. Type species: *Trochus conulus* Linnaeus, 1758, by subsequent designation of Herrmannsen, 1846, Gen. Malac., v. 1, p. 154.

CALLIOSTOMA n. sp.
Pl. 65, fig. 9

Shell small, stout, conical, consisting of five whorls; sutures slightly impressed; whorls almost straight sided, plain except for very weak narrow sutural bands above and below sutures; body whorl of about same size as last spiral whorl, anterior border subcarinate; aperture unavailable in figured specimen; spiral angle 65°.

Figured specimen.—Collected from the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Dimensions.—Height 7 mm., diameter 6.5 mm.

Discussion.—Due to the absence of most of the body whorl in the only specimen and the consequent lack of the apertural and umbilical regions, the affinity of this species is doubtful, and for this reason it was not named. The form has no close relatives in the described Cretaceous faunas.

Subfamily ANGARIINAE Thiele
Genus ANGARIA Röding, 1798

Angaria Röding, 1798, Mus. Bolten, v. 2, p. 71. Type species: *Turbo delphinus* Linnaeus, 1758, by subsequent designation of Fischer, 1875, in Kiener, Coq. Vivantes, v. 12, p. 58.

ANGARIA KEENAE von der Osten, n.sp.
Pl. 65, fig. 1

Shell small, stout, conical, consisting of three or four convex whorls; sutures very slightly impressed; sculpture of 17 evenly spaced spiral rows of hollow spines, only seven being visible on spire, on spire whorls third row strongest, giving whorl a slightly shouldered appearance, on body whorl strong row of spines more prominent, forming a spiny ridge; spines with isotriangular bases, smallest angle pointing backwards; umbilicus small; aperture almost round; inner lip slightly thickened, reflexing over umbilicus; spiral angle 70°.

Holotype.—Collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 132. *Paratype.*—Shell, smaller than holotype, collected at same locality.

Dimensions.—Height of body whorl 9 mm., diameter 14 mm., total height 15 mm. (missing tip of spire), diameter of aperture 6 mm.

Discussion.—This species bears some similarity to *Angaria lima* (Lamarck) from the Eocene of the Paris basin, which has the same type of sculpture but differs in the size of the spire. There is also some similarity with the Jurassic species *Turbo globatus* d'Orbigny and *T. epulus* d'Orbigny, but it differs from these in general shape and in sculptural detail.

Genus METRIOMPHALUS Cossmann, 1915

Metriomphalus Cossmann, 1915, Essais Paleoconch. Comp., v. 10, p. 222. Type species: *Turbo davousti* d'Orbigny, 1847, by original designation.

METRIOMPHALUS SCHWARKI von der Osten, n. sp.
Pl. 65, fig. 20

Shell of medium size, stout, conical, consisting of four convex whorls; sculpture of 19 spiral lines nine being visible on spire; of lines visible on spire, first four moderately weak, expanding in size, fifth and seventh strongest, giving whorl shouldered appearance, sixth and eighth weakest, ninth strong; on body whorl eleventh and fifteenth also strong, twelfth, seventeenth and eighteenth moderately strong, all others weak; spiral lines always narrower than interspaces; on base growth-line forming moderately strong costae, diminishing in strength upwards, causing serrations on stronger spiral lines; umbilicus small; aperture unavailable on holotype; spiral angle 75°.

Holotype.—Collected from the base of the Taguarumo member of the Barranquín formation at MMH locality Su 90.

Dimensions.—Height of body whorl 11 mm., diameter 19 mm., total height 18 mm.

Discussion.—The species bears some resemblance to Turbinidae from the Texas Cretaceous, especially *Turbo belviderensis* Stanton, but it is distinguished by its ornamentation.

METRIOMPHALUS TAGUARUMENSIS von der Osten, n. sp.
Pl. 65, fig. 22

Shell small, stout, conical, consisting of four whorls; sutures slightly impressed;

whorls almost rectangular, straight sided; sculpture of 14 serrate spiral lines, of which only six are visible on spire; strong third and sixth lines giving whorls rectangular shape, first two and fourth and fifth lines moderately weak; other lines, visible on convex base of shell, moderately strong; spiral lines and intercostal areas equal in width; serrations almost twice as wide as spiral lines, those on third and sixth lines almost spinose; umbilicus small; aperture ovate; inner lip thick, reflexed over umbilicus; spiral angle 70°.

Holotype.—Collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 130. *Paratypes.*—Two fairly well preserved shells from the same locality.

Dimensions.—Height of body whorl 6 mm., diameter 10 mm., total height 12 mm., height of aperture 4 mm., width of aperture 3 mm. Paratypes slightly larger.

Discussion.—This species, like the preceding one, bears some resemblance to the Turbinidae of the Cretaceous of Texas. It is similar to *Turbo chichuahuensis* Böse from Cerro de Muleros, Mexico, but has more ornamentation.

Order CTENOBRANCHIATA Schweigger
Suborder GYMNOGLOSSA Gray
Family EULIMIDAE Fischer
Genus EULIMA Risso, 1826

Eulima Risso, 1826, Hist. Nat. Europe Merid., v. 6, p. 123. Type species: *Turbo subulatus* Donovan, by subsequent designation of Herrmannsen, 1846, Gen. Malac., v. 1, p. 431.

EULIMA ALBENSIS d'Orbigny, 1842
Pl. 65, fig. 23

Eulima albensis d'Orbigny, 1842, Paléon. Fran., (1), v. 2, p. 64, pl. 155, fig. 14,15.

The species was reported by d'Orbigny from Lower Neocomian beds near Marolle (Aube).

Occurrence.—The specimen was collected in the Taguarumo member of the Barranquin formation, at MMH locality Su 90.

Suborder PTENOGLOSSA Gray
Family ARCHITECTONICIDAE Chenu
Genus ARCHITECTONICA Röding, 1798

Architectonica Röding, 1798, Mus. Bolten, v. 2, p. 78. Type species: *Trochus perspectivus* Linnaeus, 1758, =*Architectonica perspectiva* Röding, 1798, by subsequent designation of Gray, 1847, Proc. Zool. Soc., v. 4, p. 151.
Solarium Lamarck, 1799, Mem. Soc. Hist. Nat. Paris, v. 1, p. 74.

ARCHITECTONICA PLANORBIS (Roemer), 1888
Pl. 65, fig. 6,10

Solarium planorbis Roemer, 1888, Pal. Abh., v. 4, p. 293, pl. 31, fig. 14a–14c.
Solarium chickasaense Cragin, 1895, Colorado Coll. Studies, 5th Ann. Pub., p. 63.
Solarium pseudoplanorbis Ikins, 1940, Bull. Amer. Paleont., n. 96, p. 13, pl. 2, fig. 4a–4c.
Solarium ? planorbis Roemer. Stanton, U. S. Geol. Survey, Prof. Paper 211, p. 64, pl. 55, fig. 23–26, 1947.

The species is known from the Edwards limestone of Texas and from the Comanche Creek limestone of Oklahoma.

Occurrence.—The specimen was collected at the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Family NATICIDAE Forbes
Genus NATICA Scopoli, 1777

Natica Scopoli, 1777, Intro. Hist. Nat., p. 392. Type species: *Nerita vitellus* Linnaeus, 1758, by subsequent designation of Harris 1897, Cat. Tert. Moll. Brit. Mus., pt. 1, p. 255.

NATICA BULIMOIDES (Deshayes), 1842
Pl. 65, fig. 24

Ampullaria bulimoides Deshayes, 1842, Mém. Geol. Soc. de France, v. 5, pt, 1, pl. 16, fig. 9. (fide d'Orbigny)
Natica bulimoides (Deshayes). d'Orbigny, Paléon. Fran., (1), v. 2, p. 153, pl. 172, fig. 2,3, 1842.
Natica cf. *N. bulimoides* (Deshayes). Weaver, Mem. Univ. Washington, v. 1, p. 374, pl. 43, fig. 289,290, 1931.

The species was found in the upper part of the Agrio formation of Argentina by Weaver. It is common in the lower and middle Neocomian of France and Switzerland, according to d'Orbigny and Weaver.

Occurrence.—The specimen was collected from the Morro Blanco member of the Barranquín formation, at MMH locality Su 216.

Genus PRISCONATICA Gabb, 1877

Prisconatica Gabb, 1877, Jour. Acad. Nat. Sci. Philadelphia, (2), v. 8, p. 277. Type species: *Natica pedernalis* Roemer, 1852, by original designation.

PRISCONATICA PRAELONGA
(Leymerie), 1842
Pl. 65, fig. 8

Natica praelonga Leymerie, 1842, Mem. Soc. Geol. Paris, v. 5, p. 13, pl. 16, fig. 8. (fide White)
——. d'Orbigny, Voy. America Mérid., v. 3, p. 73, pl. 18, fig. 4, 1842. (fide White)
Prisconatica praelonga (Leymerie), White, Cont. Paleon. Brazil, p. 186, pl. 16, fig. 1–4, 1888.

The species is recorded from Brazil by White, from Colombia by d'Orbigny, and from France by Leymerie.

Occurrence.—The specimen was found in the Taguarumo member of the Barranquín formation, at MMH locality Su 132.

Genus LUNATIA Gray, 1847

Lunatia Gray, 1847, Proc. Zool. Soc. London, v. 15, p. 149. Type species: *Natica ampularia* Lamarck, 1822, by original designation.

LUNATIA CRAGINI Stanton, 1947
Pl. 65, fig. 13

Lunatia cragini Stanton, 1947, U. S. Geol. Survey, Prof. Paper 211, p. 65, pl. 52, fig. 1–3.

Stanton reports the species from the Kiowa shale of Kansas, which according to him is of upper Middle Albian age.

Occurrence.—The specimen was collected at the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Genus TYLOSTOMA Sharpe, 1849

Tylostoma Sharpe, 1849, Jour. Geol. Soc. London, v. 5, p. 378. Type species: *Tylostoma globosum* Sharpe, 1849, by subsequent designation of Wenz, 1941, Hand. Paleoz. Gast., v. 5, p. 1027.

TYLOSTOMA n. sp.
Pl. 65, fig. 3

Shell of moderate size, globose, consisting of four whorls; sutures deeply impressed; whorls smooth, convex, with strong varices at intervals of about 190°; spire compressed, only one-seventh the height of the shell; body whorl strawberry-shaped, with wide, rounded, posterior shoulder; varices well marked; umbilicus moderately large; outer lip greatly expanded; aperture pear-shaped, narrow posteriorly; spiral angle 125°.

Figured specimen.—A well preserved internal mold, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 92.

Dimensions.—Height 21 mm., diameter 17 mm., height of body whorl 18 mm.

Discussion.—This differs from all other American Cretaceous species of *Tylostoma* in the small size of the spire, the relation of the spire to the body whorl being more like that common in *Gyrodes*. Its form is very close to the English Cretaceous species *T. globosum*, however, which was selected by Wenz as the type species of the genus. Furthermore, the presence of the strong varices excludes the form from *Gyrodes* and places it in *Tylostoma*.

Genus PSEUDAMAURA Fischer, 1887

Pseudamaura Fischer, 1887, Man. Conch., p. 767. Type species; *Natica bulbiformis* Sowerby, 1835, by monotypy.

PSEUDAMAURA sp. cf. P. BULBIFORMIS
(Sowerby), 1835
Pl. 65, fig. 2

Natica bulbiformis Sowerby, 1835, Trans. Geol. Soc. London, (2), v. 3, p. 418, pl. 38, fig. 13.

Several large shells, badly preserved and crushed longitudinally, were collected in the Santa Fé region. They consist of five whorls, shouldered, with a concave upper border and almost vertical sides, which join in a continuous wall along the upper edge of the whorls. The body whorl is two-thirds the total height of the shell, slightly convex, vertical sided for half its length, then convexly tapering to a point at the lower end of the aperture, which was probably ovulate or egg-shaped. No umbilicus is present. The surface is so badly pitted and scarred that the ornamentation cannot be deduced. There is a suggestion that strong radial ribs, about 12 to the whorl, may have been present but this may be only an effect of weathering. The height of the shell is 60 mm. and the diameter averaging the greatest and least widths, is 33 mm. The spiral angle was appropriately 80° before deformation.

These shells represent a species closely related to the type species of the genus, *Pseudamaura bulbiformis*, from the Turonian of Switzerland (Gosau), which is strikingly similar. Better preserved material is needed, however, to establish definitely their identity with this form, or to describe formally a new species.

Family TURRITELLIDAE Gray
Genus TURRITELLA Lamarck, 1799

Turritella Lamarck, 1799, Mem. Soc. Hist. Nat. Paris, (1) v. 1. p. 74. Type Species: *Turbo terebra* Linnaeus, 1758, by monotypy.

TURRITELLA MINISTERI von der Osten, n. sp.
Pl. 65, fig. 27

Shell moderately large, conical, whorls straight, sutures incised; spire with at least five whorls (body whorl, top of spire, and aperture absent in holotype); height of whorls almost one-half width, sides almost flat, with slight undulations and a strong sutural band just below suture; sculpture of many fine lines, very faint on holotype; growth lines occasionally well marked; spiral angle 30°.

Holotype.—Fragment of shell with two complete whorls and parts of two others, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 110.

Dimensions.—Height of fragment 35 mm., greatest diameter 23 mm., probable original height about 50 mm.

Discussion.—No forms closely related to this species have been described from the Cretaceous of Texas. It bears some resemblance to *Turritella potosiana* from the Senonian of Mexico (Cardenas, San Luis Potosi), but differs from this species in its almost flat whorls and lack of any prominent spiral ornamentation.

TURRITELLA PELUSAE von der Osten, n. sp.
Pl. 65, fig. 15

Shell elongate, conical, whorls concave, sutures deeply impressed; spire with seven or eight whorls, three or four lacking in the holotype; height of whorl one-half of width; sculpture of five serrate spiral ribs on each whorl, equal in size, about one-third as wide as intercostal areas; body whorl twice the height of the last spire-whorl, with one additional rib; base somewhat flattened, with several spiral lines; aperture not preserved; spiral angle 13°.

Holotype.—Fragment of shell with four complete whorls, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 110.

Dimensions.—Height of preserved portion of shell 21 mm., greatest diameter 8.5 mm.

Discussion.—The species is similar to *Turritella difficilis* d'Orbigny but is distinguished by its smaller size, its smaller spiral angle, and the presence of six smooth spiral ribs. It is distinguished from *T. vertebroides* d'Orbigny also by its smaller size and smaller spiral angle, and by its lack of finer secondary ribs in the intercostal areas.

TURRITELLA SERIATIM-GRANULATA Roemer, 1849
(Pl. 65, fig. 7)

Turritella seriatim-granulata Roemer, 1849, Texas, p. 413. (fide Stanton)
——. Roemer, Kreideb. v. Texas, p. 39, pl. 4, fig. 12a,12b, 1852.
——. Gabb, Paleontology of California, v. 2, p. 227,263, 1868.
——. Stanton, U. S. Geol. Surv., Prof. Paper 211, p. 75, pl. 56, fig. 7,11,17–24, 1947.

A single well preserved specimen, found in the Santa Fé area, is in acccordance with Roemer's description of the species. It also matches closely Stanton's figure 24, which is said by him to represent one of Gabb's specimens from the Potrero formation, near Arivechi, Sonora, Mexico (Gabb, *op. cit.*, p. 263). Although there is little doubt that the Santa Fé and the Mexican specimens belong in the same species, these are quite different from other Texas specimens that Stanton figures as *Turritella seriatim-granulata* Roemer. Perhaps the Venezuelan and Mexican specimens should be considered as a different species, *T. seriatim-granulata* Gabb, *non* Roemer, but these are as adequately described by Roemer's text as the Texas specimens, and so can be considered as a southern variety of the species.

Occurrence.—The specimen was found in the Taguarumo member of the Barranquín formation, at MMH locality Su 109.

Family NERINAEIDAE Zittel
Genus NERINAEA Deshayes, 1827

Nerinaea Deshayes, 1827, Dict. Class. Hist. Nat., v. 11, p. 535. Type species: *Nerinaea mosae* Deshayes, 1827, by monotypy (*fide* Allison).
Nerine Defrance, 1824, Bull. Univ. Sci. Nat., p. 284, and Dict. Sci. Nat., v. 34, p. 462, 1825, vernacular. Cited by subsequent authors as *Nerinea* Defrance.

NERINAEA DIANAE von der Osten, n. sp.
Pl. 65, fig. 19

Shell of medium size, elongate, conical, whorls concave, suture conspicuous; spire with more than five whorls (top of spire absent in holotype); height of whorls one-half width, gently concave in middle, elevated posteriorly to form a narrow subangular ridge just below suture, anterior elevation not forming ridge in spiral whorls; sculpture of 10 generally weak spiral lines, locally one or several appearing slightly stronger than the others; anterior border of body whorl carinate, produced into a prominent, deflected anterior canal; interior with one strong fold on inner lip, one high narrow fold on outer lip, one small fold on columella; spiral angle 14°.

Holotype. A fairly well preserved shell, lacking the top of the spire, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 110. *Paratype.*—A fragment of shell with the surface sculpture preserved, collected at the same locality.

Dimensions.—Height of broken shell 32 mm., diameter 13 mm., probable original height 58 mm.

Discussion.—The species is very similar in general appearance to *Nerinaea burckhardti* Böse from the Senonian of Mexico but is differentiated by the presence of surface sculpture and the more complicated interior of the Mexican species.

NERINAEA HICORIENSIS Cragin, 1893
Pl. 65, fig. 17

Nerinaea hicoriensis Cragin, 1893, Geol. Surv. Texas, 4th Ann. Rept., p. 225, pl. 42, fig. 6.
——. Adkins, Univ. Texas Bull., n. 2838, p. 186, 1928.
——. Stanton, U. S. Geol. Surv., Prof. Paper 211, p. 83, pl. 58, fig. 2–4, 1947.

The species is common in the Travis Peak formation of Texas.

Occurrence.—The specimen is from near the base of Targuarumo member of the Barranquín formation, at MMH locality Su 92.

NERINAEA PSEUDOCONVEXA
Stanton, 1947
Pl. 65, fig. 16

Nerinaea pseudoconvexa Stanton, 1947, U. S. Geol. Surv., Prof. Paper 211, p. 87, pl. 60, fig. 8,10–12.

The types of this species are from the Edwards limestone, near Austin, Texas. According to Stanton, the species is also known from the Glen Rose formation, at Glen Rose, Texas.

Occurrence.—The specimen was collected at the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

NERINAEA RIVERAE von der Osten, n. sp.
Pl. 65, fig. 25

Shell medium size, elongate, whorls slightly concave, sutures impressed; spire with more than six whorls (top of spire absent in holotype); height of whorls two-thirds width, gently concave posteriorly, flat to weakly convex anteriorly, forming expansion above suture; sculpture of weak spiral lines (number and pattern impossible to ascertain on holotype due to weathering and affixed matrix; anterior border of body whorl sub-carinate; interior with one high narrow fold on inner lip and one low wide fold on columella; spiral angle 10°.

Holotype.—The lower portion of a shell, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 109.

Dimensions.—Height of broken shell 58 mm., diameter 19 mm., probable original height 110 mm.

Discussion.—This species differs from described Nerinaeidae of the Caribbean Cretaceous in the concavo-convex form of the whorls, and no closely related form was noticed in the literature.

NERINAEA ROEMERI Whitney, 1952
Pl. 66, fig. 21

Nerinaea sp. indt. Roemer, Texas, p. 412, 1849, (*fide* Whitney)
Nerinaea sp. indt. Roemer, Kreidb. v. Texas, p. 41, pl. 4, fig. 8, 1852.
Nerinaea roemeri Whitney. Jour. Paleontology, v. 26, p. 71, pl. 14, fig. 1,2,1952.

Roemer figures a cast of a specimen which Whitney refers to this species, but it appears to be quite different from her figures and from the Santa Fé specimen. This reference seems further unjustified if the lack of information pertaining to the internal structure of Roemer's specimen is considered.

The species is described from the Glen Rose formation of Texas.

Occurrence.—The specimen was collected near the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 92.

NERINAEA TRISHAE von der Osten, n. sp.
Pl. 65, fig. 4,5

Shell moderately small, conical, whorls concave, sutures inconspicuous; spire with nine whorls; height of whorl about one and one-half times the width; ornamentation of seven spiral ribs, first and last strongest, forming wide, high ridge with suture in middle, second and sixth spiral ribs slightly weaker, fused into sutural ridge, middle three only moderately strong, equal, separated by equal interspaces; spiral ribs crossed by radial ribs or "highs," forming prominent nodes on sutural ridges, about eleven to the whorl; interspaces narrower than ribs; anterior border of body whorl carinate, produced into prominent anterior canal; bottom slightly concave, with two spiral lamellae, radial ribs present; interior with one strong fold on outer lip, two moderately strong folds on inner lip, and two weak folds on columella; spiral angle 28°.

Holotype.—A nearly complete shell, collected from the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Dimensions.—Height 36 mm., diameter 11 mm.

Discussion.—This species has an ornamention quite dissimilar to that of other Cretaceous Nerinaeidae, and no related form either from Europe or American is known.

Family CERITHIDAE Menke
Genus CERITHIUM Bruguière, 1789

Cerithium Bruguière, 1789, Ency. Meth., (Vers), v. 1, p. 15, (p. 467 in 1792). Type species: *Cerithium virgatum* Montfort, 1810 = *Murex vergatus* Linnaeus, 1758, by subsequent designation of Montfort, 1810, Conchy Syst., p. 511.

CERITHIUM KRAUSKOPFI von der Osten, n. sp.
Pl. 65, fig. 14

Shell small, conical, whorls slightly convex, sutures impressed; spire with six whorls; height of whorl about one-third width; ornamentation of seven strong radial ribs per whorl, anteriorly inclined downwards; rib on each whorl located more anteriorly than those on preceding whorl, giving spire a twisted appearance; interspaces four or five times as wide as ribs, crossed by six or seven spiral threads; body whorl about four times height of last spiral whorl, with strong spiral threads; anterior border rounded; two spiral lamellae on bottom; aperture not available in holotype; spiral angle 40°.

Holotype.—A nearly complete shell, collected from the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Dimensions.—Height 12 mm., diameter 4.5 mm.

Discussion.—There are no known Cretaceous forms related to this species. It is very similar to *Cerithium lamellosum* Bruguière from the Lutetian of Grignon, France, especially the individual illustrated on plate 9, figure 143, of the first part of the "Catalogue Illustré de la Collection Lamarck" (Genèva, 1918), and probably represents an ancestral form. The spiral threads are much stronger in the Eocene form, however, the lamellae on the base are better developed, and these are three in number.

Genus GYMNOCERITHIUM Cossmann, 1906

Gymnocerithium Cossmann, 1906, Essais Paléoconch. Comp., v. 7, p. 36. Type species: *Cerithium collegiale* Zittel, by original designation.

GYMNOCERITHIUM LISUM von der Osten, n. sp.
Pl. 65, fig. 18

Shell small, conical, whorls straight, sutures impressed; spire with eight or nine whorls, one or two lacking in holotype; height of whorl about one-third width; sculpture smooth, a suggestion of fine spiral lines eroded from holotype; body whorl about twice the size of last spiral whorl, anterior border rounded, produced into narrow anterior canal, faint growth-lines visible on bottom; aperture ovulate; spiral angle 30°.

Holotype.—A nearly complete shell, slightly deformed by shearing parallel to longitudinal axis, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 130.

Dimensions.—Height of incomplete shell 30 mm., diameter 12.5 mm., probable original height 35 mm.

Discussion.—The species can be compared with a form recorded by Böse (1906, p. 62) as *Turritella cardenasense*, from the Senonian of Cardenas, but is differentiated by the presence of surface ornamentation in the latter species. It is probably related to *Gymnocerithium icaunense* (Cossmann) from the Neocomian of Yonne, but it is shorter and stouter than this French species.

Family APORRHAIDAE Phillippi
Genus ANCHURA Conrad, 1860

Anchura Conrad, 1860, Jour. Acad. Nat. Sci. Philadelphia, (2) v. 4, p. 284. Type species: *Anchura abrupta* Conrad, 1860, by monotypy.

ANCHURA CATEDRALIS von der Osten, n. sp.
Pl. 65, fig. 11,12

Shell large, fusiform, whorls slightly convex, sutures incised; spire of four or five whorls; height of whorls almost one-half of width; sculpture of strong, wide, radial ribs, anteriorly inclined downwards, nodose posteriorly, becoming strong nodes in body whorl, about 11 to the whorl, crossed by approximately 44 fine spiral threads, arranged in bands of one stronger thread followed by three weaker; growth-lines faintly marked; body whorl about three times height of last spiral whorl; posterior portion of outer lip thickened, extending upwards and outwards, forming a thick, almost rectangular process, possibly alate downwards (not present in holotype), reaching to about center of preceding whorl; inner lip thickened; aperture long, extending into anterior canal, unavailable in holotype; spiral angle 35°.

Holotype.—A well preserved shell, lacking the top of the spire, a part of the anterior canal, and a portion of the alate process, collected from the base of the Taguarumo member of the Barranquín formation, at MMH locality Su 90.

Dimensions.—Height of incomplete shell 60 mm., diameter 23 mm., probable original height 70 mm.

Discussion.—This species bears little resemblance to other Cretaceous Anchuras form North America, with the exception of *Anchura plenecosta* Stephenson from the Navarro group of Texas. It is however much larger than the Texas species, the orientation of the alate process is downwards instead of upwards, and the whole aspect of the shell is coarser. This latter is true also for its comparison with the other Texas Anchuras, which have a more delicate aspect.

ANCHURA SUCRENSIS von der Osten, n. sp.
Pl. 65, fig. 26

Shell of medium size, fusiform, whorls convex, sutures incised; spire of three or four whorls; height of whorls about two-thirds width; sculpture of strong radial ribs, concave towards aperture, center thickened almost into nodes, about eight to the whorl, crossed by approximately 25 fine spiral threads; growth-lines forming fine radial threads, slightly weaker than spiral sculpture; body whorl at least twice height of last spiral whorl (lower part absent in holotype); posterior portion of outer lip thickened, extending outwards and upwards, forming undulating wing-like process (broken off in holotype), reaching as high as top of last spiral whorl, with strong fold in line with nodes on ribs; aperture long, incomplete in holotype; spiral angle 50°.

Holotype.—An incomplete shell, collected from the Taguarumo member of the Barranquín formation, at MMH locality Su 92.

Dimensions.—Height of broken shell 21 mm., diameter 10 mm., probable original height 27 mm.

Discussion.—This species is similar to other Cretaceous Anchuras from Kansas and Texas but differs in having fewer spiral ribs per whorl. Being less numerous, the ribs are stronger and have more pronounced nodes than in the North American species. It is closest to *Anchura kiowana*, from the Kiowa shale of Kansas, which has 24 radial ribs per whorl, as compared to eight in *A. sucrensis.*

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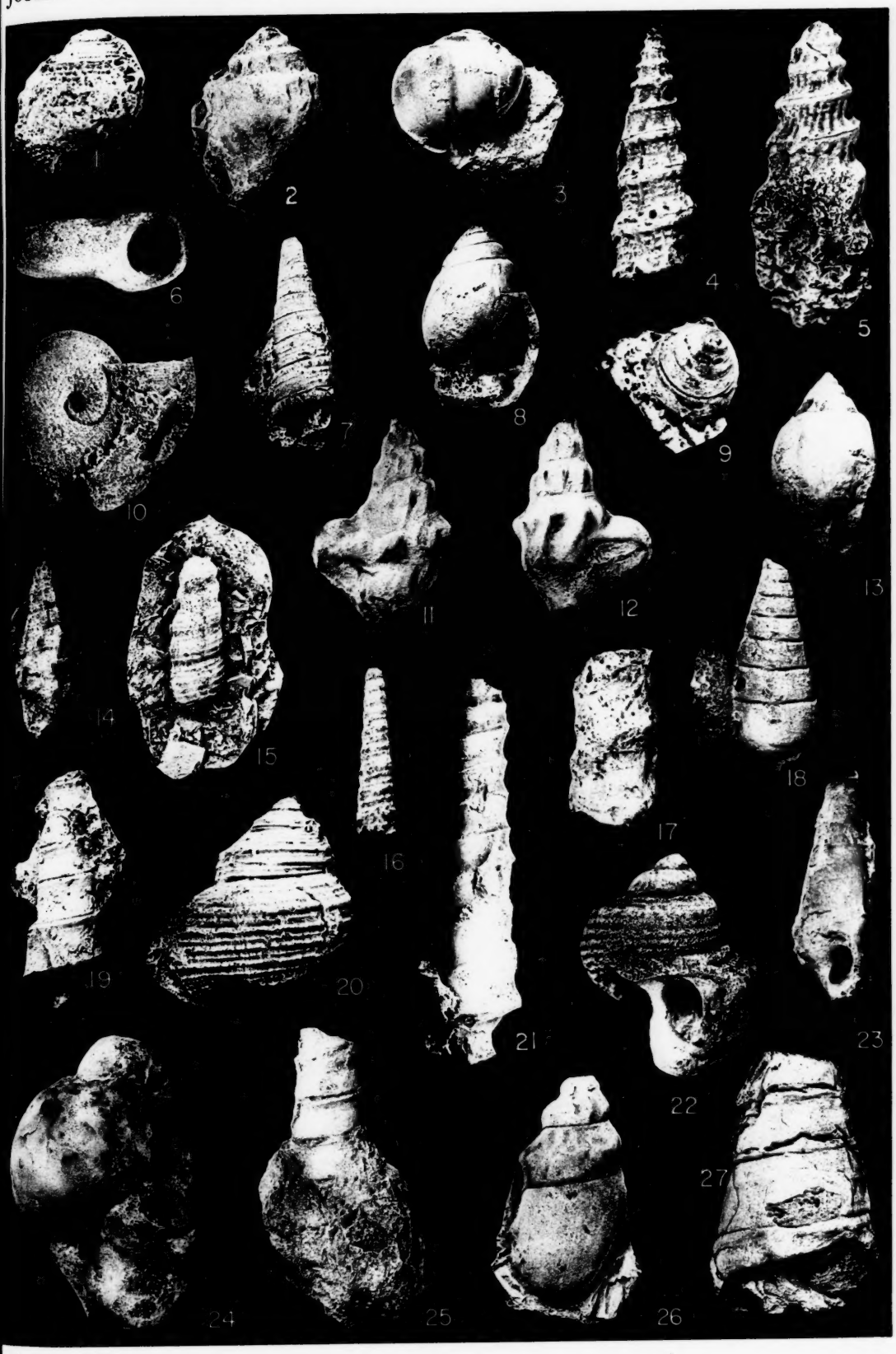
MANUSCRIPT RECEIVED AUGUST 27, 1956

EXPLANATION OF PLATE 65

FIG. *1*—*Angaria keenae*, n. sp., ×1.8.
2—*Pseudamaura* sp. cf. *P. bulbiformis* (Sowerby), ×0.56.
3—*Tylostoma* n. sp., ×1.8.
4—*Nerinaea trishae*, n. sp., ×2.2, holotype.
5—*Nerinaea trishae*, n. sp., ×2.9, paratype, detail of sculpture.
6—*Architectonica planorbis* (Roemer), ×2.9, apertural view.
7—*Turritella seriatim-granulata* Roemer, ×1.2, apertural view.
8—*Prisconatica praelonga* (Leymerie), ×0.67, apertural view.
9—*Calliostoma* n. sp., ×2.64,
10—*Architectonica planorbis* (Roemer), ×3, umbilical view.
11—*Anchura catedralis*, n. sp., ×0.59.
12—*Anchura catedralis*, n. sp., ×0.59.
13—*Lunatia cragini* Stanton, ×1.2.
14—*Cerithium krauskopfi*, n. sp., ×2.7.
15—*Turritella pelusae*, n. sp., ×1.2.
16—*Nerinaea pseudoconvexa* Stanton, ×2.5.
17—*Nerinaea hicoriensis* Cragin, ×0.67.
18—*Gymnocerithium lisum*, n. sp., ×1.24.
19—*Nerinaea dianae*, n. sp., ×1.3.
20—*Metriomphalus schwarki*, n. sp., ×1.88.
21—*Nerinaea roemeri* Whitney, ×1.2.
22—*Metriomphalus taguarumensis*, n. sp., ×3.4, apertural view.
23—*Eulima albensis* d'Orbigny, ×2.5, apertural view.
24—*Natica bulimoides* (*Deshayes*), ×0.55.
25—*Nerinaea riverae*, n. sp., ×0.64.
26—*Anchura sucrensis*, n. sp., ×1.8.
27—*Turritella ministeri*, n. sp., ×1.1.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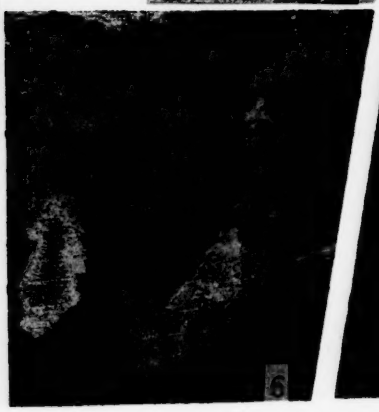
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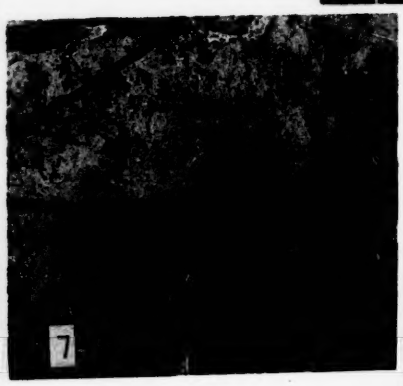
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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 591–594, PL. 66, MAY 1957

THE SIPHUNCLES OF SOME COILED NAUTILOIDS FROM THE LOWER PERMIAN OF BAYLOR COUNTY, NORTH-CENTRAL TEXAS

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ABSTRACT—Information regarding the siphuncles of coiled Permian nautiloids is scanty and illustrations of their structure very scarce. This is partly due to the infrequency of the preservation of siphuncles and to the scarcity of sectionable material.

A single fortunate outcrop of well preserved nautiloids has enabled the writer too make over a hundred sections showing structural details, of which more than sixty showed siphuncles. Among these *Tainoceras* predominated. In the outer whorl its septal necks are sometime straight, sometime recurved. Its rings are expanded within the camerae. The siphuncles of *Temnocheilus*, *Knightoceras*, *Metacoceras*, and *Liroceras* closely resemble those of *Tainoceras*. Except in *Liroceras*, they all lie somewhat ventrad of the center of the whorl. The siphuncle of *Stenopoceras* lies quite close to the venter, though not on it, and its rings are only slightly convex outward. The siphuncle of *Domatoceras* closely resembles that of *Stenopoceras*. In the inner whorls the siphuncles of all the above genera are nearly cylindrical and not distinguishable from each other.

The crystalline deposits in camera and siphuncle are most probably of inorganic origin.

INTRODUCTION

DESCRIPTIONS of the siphuncles of coiled Permian nautiloids are infrequent and brief and their scarce illustrations usually show only the location of the siphuncle in the septum. This is probably because the siphuncle is not often preserved, or when present, is in material which sections poorly, if at all. Nor have the fact that Permian nautiloids are poor index fossils and their specimens are usually heavy and clumsy, contributed to their popularity with collectors.

This scarcity of information regarding the siphuncles of coiled Permian nautiloids holds true for their Triassic descendents, and, to a lesser extent, for their Pennsylvanian forebears. A fairly extensive search of the American literature yielded no section of a coiled Triassic nautiloid and only two of Permian ones, each showing only septal necks. In comparison, sections of Pennsylvanian siphuncles are almost common, perhaps five per cent of the descriptions of such siphuncles being accompanied by sections.

EXPLANATION OF PLATE 66

All illustrated specimens came from the Grape Creek limestones of the (Lower Permian), Clyde formation 1½ miles NNE of the England schoolhouse and 10 miles E of Seymour, Texas. The numbers in parentheses are their catalog numbers in the A. H. Kemp collection.

FIG. *1—7—Trainoceras clydense* Miller & Kemp, topotypes. *1*, (638×) Cross section showing outer whorl with ring of radiating crystals around siphuncle and inner whorl showing siphuncle, ×3.6. *2*, (629) Longitudinal section showing siphuncle passing through seven successive camerae. This is apparently the replacement and filling of the original fleshy siphon, ×2.7. *3*, (640.3) Longitudinal section of siphuncle at about the end of the first whorl, rings almost cylindrical, ×3.3. *4*, (630.×) Longitudinal section showing rings and necks. The endings of three of the latter are straight; three are knobbed, indicating brims, ×4. *5,6*, (792.1 and 637.2) Longitudinal sections showing necks and rings, ×4.4. *7*, (636d) Longitudinal section of abnormal ring, ×4.4.

8—Temnocheilus coronatum McCoy. (650) Natural tangential section which apparently shows the replacement and amorphous fillings of the siphon, ×3.

9,10—Stenopoceras whitei Miller & Youngquist, paratypes. *9*, (680) Longitudinal section showing necks and rings of siphuncle through four successive camerae. The arrow marks the venter, ×2.7. *10*, (680) A natural break shows the replaced siphon with oblique constrictions at its passage through the septa, ×4.6.

The following illustrations of sections of siphuncles of coiled Pennsylvanian nautiloids were found:

Domatoceras williamsi (Miller, 1934, pl. 14, fig. 4).
Domatoceras obsoletum (Sturgeon, 1946, pl. 8, fig. 3).
Ephippioceras ferratum (Sturgeon, 1946, pl. 4, fig. 2).
Knightoceras abundum (Miller, 1947, fig. 2)
Koninckioceras (Newell, 1936, fig. 1, p. 487).
Liroceras liratum (Sturgeon, 1946, pl. 4, fig. 6).
Liroceras [as *Coloceras*] *liratum* (Newell, 1936, pl. 68, fig. 2).
Liroceras [as *Coloceras*] *obsoletum* (Miller, 1933, pl. 7, fig. 6).
Metacoceras angulatum (Miller, 1933, pl. 15, fig. 4).
Solenocheilus peculiare (Miller, 1933, pl. 9, fig. 1).
Solenocheilus greenensis (Sturgeon, 1946, pl. 9, fig. 3).

This study is based, almost entirely, on material found at an outcrop of Grape Creek limestone, Clyde formation of the Lower Permian, at the "England ammonoid" locality 10 miles east and 1½ miles north of Seymour, Baylor County, Texas. Sections showing structural details numbered:

Tainoceras clydense Miller & Kemp	65
Stenopoceras whitei Miller & Youngquist	21
Temnocheilus coronatum McCoy	17
Knightoceras kempae Miller & Youngquist	7
Metacoceras sp.	6
Liroceras sp. cf. *L. globulare* Hyatt	4
Domatoceras spp. of Texas Miller & Youngquist	2

Over half of these sections showed siphuncles.

ACKNOWLEDGMENTS

Most of the sectioning was done in the geological laboratory of the State University of Iowa. Thanks are due Dr. A. K. Miller for checking the writer's identification of the nautiloids, and for his continued interest in the work; also to Mr. Frederick Kent, University Photographic Service, Iowa City, Iowa, for making the photographs.

SIPHUNCLES

In fossil forms the term siphuncle covers not only the necks and rings of the original calcareous tube, but also any filling and replacement of it or the fleshy siphon. In the Permian genera herein discussed, the siphuncle is a continuous tube of varying diameter. The necks are usually straight and short. If they turn outwards at their adapical ends, they are said to have a brim (Miller, 1933, p. 29, text-fig. 5). In some of the sections the rings alone appear to form a continuous tube, with its present filling different from that in the camerae (pl. 66, fig. 2). This could be a replacement and filling of the original fleshy siphon.

Kummel (1953, p. 51) suggests that the variations in the position of the siphuncle be expressed as a per cent of the distance from the venter to the siphuncle to the height of the whorl. Wherever the preservation of the section permitted, the averages of these per cents have been calculated, for inner and outer whorls separately, as given below:

Nautiloids	No. cases for outer whorl	Per cent of outer whorl height	Per cent of inner whorl height
Knightoceras kempae	—	—	33
Liroceras cf. *L. globulare*	7	68	—
Metacoceras sp.	3	46	—
Stenopoceras whitei	9	19	21
Tainoceras clydense	24	40.6	37.5
Temnocheilus coronatum	10	33	—

To show the degree of the variation of the siphuncle from a cylindrical shape in the outer whorls, the writer has measured the maximum diameter of the siphuncle, usually in mid-camera, and the corresponding minimum diameter, at the septal foramen, and expressed their ratio as a per cent. Obviously 100% would indicate a perfect cylinder. Apparently abnormal measurements for *Tainoceras* and *Metacoceras* were not used in making the calculations for the following table.

Nautiloids	(Maximum diameter of siphuncle as per cent of minimum
Knightoceras kempae	200
Liroceras cf. *L. globulare*	133
Metacoceras sp.	185
Stenopoceras whitei	115
Tainoceras clydense	180
Temnocheilus coronatum	160

DESCRIPTIONS OF SIPHUNCLES BY GENERA

Tainoceras (pl. 66, fig. 1–7).—It is the exceptional *Tainoceras* specimen which shows three whorls, usually there are two or less. The phragmocone is typically nearly two whorls long. In no case is the *Tainoceras* siphuncle a true cylinder, for in longitudinal section the walls are not straight. It narrows

in the septal foramina and widens in the intra-cameral spaces. The siphuncle of *Tainoceras* consists of septal necks, which extend through one-tenth to one-fifth of the cameral length, and connecting rings which extend from the ends of the necks to the preceding adapical septa (pl. 66, fig. 4–6). These rings are curved convexly outward. In the inner whorl the diameter of the siphuncle in mid-camera averaged 110% of that in the septal neck. In the outer whorl, abnormal cases excluded, these ratios (9 cases) were 130–210%, averaging 180%. This per cent apparently increases adorally. In three cases the longitudinal section of a ring was circular, so that this per cent was 300 or more. These latter cases are either pathogenic or due to distention by gases from postmortem decay. Some authors think that in life the rings were capable of distention and contraction to regulate the density of the animal (pl. 66, fig. 7).

Following Kummel, the ratio of the distance from the venter to the center of the siphuncle, and the height of the whorl at that point, were expressed as per cents. These distances were measured for about 30 cases, the maximum deviations from an average of 40% were 15 plus and 12 minus. With seven pairs of measurements for the inner (pl. 66, fig. 3) whorl only, this per cent was 37.5. This seems to suggest that the siphuncle in the inner whorl is relatively slightly closer to the venter than in the outer whorl, but the shorter distances would increase the experimental error. Calculations for the outer whorl only give 40.6%. So, broadly speaking, the *Tainoceras*, siphuncle lies barely closer to the center of the camera than it does to the venter.

Many of the septal necks are straight, but some are slightly recurved and others end (in section) in knobs, suggesting a sort of thickened brim, as in some vases, whereas the ends of the necks are often thin, as in the edge of a tea-cup. The question as to whether these knobs were due to small attached ostracods was carefully considered and answered in the negative, because: (1) The knobs were present in some sections where no ostracods occured; (2) in a number of cases the knobs occurred in pairs (pl. 66, fig. 4,5,6).

Temnocheilus (pl. 66, fig. 8).—A natural section of a *Temnocheilus coronatum* from the Elm Creek limestones of the Admiral formation near the eastern line of Baylor County shows a siphuncle 0.2 mm. in diameter surrounded by a ring of radiating crystals about 0.3 mm. wide. The siphuncle is 0.5 mm. from the venter where the camera is 4 mm. in height. This section occurs about 1½ volutions from the apex which is missing. An additional septate (?) volution is present.

In the inner whorl of other specimens the siphuncle is an almost cylindrical tube, the rings beingly only slightly, though symmetrically, expanded. The siphuncle frequently shows the distinction between rings and necks on the one hand and siphonal replacements on the other, the latter showing as a continuous tube with its interior filled with crystalline and/or amorphous matter. In both whorls the siphuncle lies conspicuously closer to the venter. The rings in the outer whorl are more or less convex outward and in a few cases are as broad as long. A few knobbed necks occur, though usually the necks are straight.

Knightoceras.—In the inner whorl the siphuncle of *Knightoceras* is an almost straight tube barely contracted at the septal foramina and with straight septal necks. In the outer whorl the maximum diameter of the rings is twice that of the necks. The siphuncle lies about midway between the venter and the center of the camera.

Metacoceras.—In *Metacoceras* the siphuncle lies at the center of the camera or just barely ventrad to it. In the outer whorl its maximum diameter is about twice its minimum. Some sections show clearly the adnation of rings to necks. Inside one such section is a continuous tube, evidently the replacement of the fleshy siphon. In a cross section the siphuncle, 0.2 mm. in diameter, is surrounded by a wider ring of radiating crystals. A similar structure is frequently seen in *Tainoceras* (pl. 66, fig. 1), *Temnocheilus*, *Liroceras*, and *Stenopoceras*.

Liroceras.—The siphuncle of *Liroceras* is indistinguishable from that of *Tainoceras* or *Temnocheilus*, except that it lies somewhat dorsad of the centers of the camerae.

Stenopoceras (pl. 66, fig. 9,10).—The siphuncle of *Stenopoceras* lies close to the venter, but not on it. The rings are only slightly expanded within the camerae. The septal necks extend straight backward one-

tenth to one-fifth the length of the camera. They lie at right angles to the septum of which they are a part, but due to the rapidly varying curvature (pl. 66, fig. 9) of a septum, in section one side of a neck is not always parallel to the other. In some sections the rings extend from the tip of the septal neck backward to the preceding septum. One partly completed section broke so as to show what seems to the replacement of the fleshy siphon. No necks are visible, but the thin outer surface is red, the interior of gray matrix, and the constrictions at each septal foramen are noticeably oblique, in line with the curvature of the septa (pl. 66, fig. 10.) The siphuncles of the inner whorls are much like those of the outer ones.

Domatoceras.—The siphuncle of *Domatoceras* closely resembles that of *Stenopoceras*, but there were too few specimens to justify measurements.

SIPHUNCULAR AND CAMERAL DEPOSITS

The question of the presence of siphuncular and cameral deposits, such as occur in *Pseudorthoceras*, was carefully considered. Cameral fillings found were amorphous matrix, irregular deposits of calcite, bands of calcite crystals parallel to the septa, crystal prisms projecting into the cameral space at right angles to septa or siphuncle, or any combination of the above. In some cases the radiating crystals seen in a cross section of a siphuncle may be traced into a plane normal to the section, where they seem to make up the walls of a ring. Could this be original structure?

Probably not because in sections in which the camerae and siphuncles are filled with matrix, the septa and walls of the rings appear as thin translucent or dark lines. But the frequency with which cross sections show a siphuncle surrounded by a ring of radiating crystals, and the fact that in many sections where the septa have been broken and dislocated, the septal fragments are bordered by crystal bands, obviously deposited *before* the septa were broken, cause one to wonder. In one section in which the rings are missing the crystal prisms radiate from the necks and extend out into the space previously occupied by rings. Some minute geoidal cavities were seen in amorphous cameral fillings. The crystalline deposits do not seem uniform enough in position nor invariable enough in occurrence to be of organic origin. A few transverse lines across the siphuncle, usually at necks, are too irregular to be anything but the fillings of cracks.

GENERAL CONCLUSIONS

In the first whorl of the genera studied, there is practically no difference in any of the siphuncles, but in the second whorl, which is usually the last whorl of the phragmocone, surprising resemblances, as well as differences, appear. The sections of siphuncles of *Tainoceras*, *Temnocheilus*, *Metacoceras*, *Liroceras*, and *Knightoceras* are hardly distinguishable from one another, while those of *Stenopoceras* and *Domatoceras* are almost alike, but very different from those of *Tainoceras*, etc.

All the above genera come within Hyatt's definition of orthochoanitic in that the funnels are, more or less, straight, and the siphuncular segments (i.e., rings) are only slightly nummuloidal, fusiform, or tubular. (Hyatt, in Zittel 1913, p. 598).

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 595–599, PL. 67–68, 2 TEXT-FIG., MAY 1957

THE CARBONIFEROUS GENERA *PALAEOCARIS* AND *EUPROOPS* IN THE CANADIAN MARITIME PROVINCES[1]

MURRAY J. COPELAND[2]

ABSTRACT—Specimens of the Carboniferous genera *Palaeocaris* and *Euproops* have not previously been reported from strata of Lower Carboniferous age in the Maritime Provinces of Canada. One new species, *P. novascoticus*, is described and a supplementary description of *E. thompsoni* Raymond is given.

INTRODUCTION

NUMEROUS fossil arthropods, collected from strata of Carboniferous age in the Maritime Provinces, have been described by Dawson (1855 et. seq.), Bell (1929), and Copeland (1956 Ms.). Unreported specimens of the genera *Paleaocaris* and *Euproops* have recently been identified from the collection of the Geological Survey of Canada. These constitute the basis for the present paper. Thanks are expressed to Dr. W. A. Bell for bringing the specimens to the author's attention and to Mr. E. C. Elliott for photography of the plates.

LOCATION AND STRATIGRAPHIC POSITION

Carboniferous sedimentary rocks cover more than one-third of the land area of the Canadian Maritimes. These strata have been divided by W. A. Bell (1929, 1944) into six stratigraphic groups as shown on the accompanying figure (text-fig. 1).

UPPER CARBONIFEROUS	PICTOU GROUP (*E. amiae*) (*P. typus*?) (*P.* sp.)
	CUMBERLAND GROUP
	RIVERSDALE GROUP (*E. danae*?)
	CANSO GROUP
LOWER CARBONIFEROUS	WINDSOR GROUP (*E. thompsoni*) (*E.* sp.)
	HORTON GROUP (*P. novascoticus*)

TEXT-FIG. *1*—Carboniferous stratigraphic chart of the Canadian Maritime Provinces.

The species described in this paper have been found separately in strata of the upper Horton, lower Winsor, and lower Pictou groups at the localities indicated on the accompanying sketch map (text-fig. 2). Other species have been reported from the Riversdale and Pictou groups (Woodward 1918, Copeland 1956 Ms.). All of these specimens have been collected from strata of non-marine origin with the exception of *E. thompsoni* which is found in strata of the Windsor group associated with a marine fauna. Whether these Windsor specimens were indigenous to a marine environment is unknown.

SYSTEMATIC DESCRIPTIONS

Phylum ARTHROPODA
Class CRUSTACEA
Subclass MALACOSTRACA
DIVISION EMUALACOSTRACA
Order ANASPIDACEA
Family PALAEOCARIDAE
Genus PALAEOCARIS

Type species.—*Palaeocaris typus* Meek and Worthen 1865.

PALAEOCARIS sp.
Pl. 67, fig. 5

This species is represented by one poorly preserved specimen showing only the body segments and telson. The shape of the telson and length of the uropods shows a possible relationship to *P. typus* Meek and Worthen.

Locality.—Near Clifton, Gloucester County, New Brunswick, collected by J. F. Whiteaves.

Type.—Hypotype, G.S.C. 13315.

[1] Published by permission of the Deputy Minister, Department of Mines and Technical Surveys, Ottawa.

[2] Geologist, Geological Survey of Canada.

TEXT-FIG. 2—Sketch map of the Maritime Provinces showing collecting localities. 1, Clifton, Gloucester County, New Brunswick. 2, Pugwash and Wallace, Cumberland County, Nova Scotia. 3, Hillsboro, Inverness County, Nova Scotia.

PALAEOCARIS NOVASCOTICUS, n. sp.
Pl. 67, fig. 4; Pl. 68, fig. 1–9

Body elongate, head and thorax nearly equal in width, abdomen tapering posteriorly. Body consisting of head, 6 thoracic segments, 6 abdominal segments, and telson; thoracic and abdominal portions nearly of equal length.

Head shield horseshoe-shaped, about one and one half times as long as wide, rounded anteriorly, abruptly truncated behind, overlapping the anterior margin of the first thoracic segment. Two pairs of antennae; first pair biramous, protopodite with three podomeres, endopodite short and thick, less than half the length of the slender exopodite; second pair of antennae uniramous, protopodite with three podomeres, bearing a setate rectangular basal scale and a slender flagellum equal to half the length of the body. Two pairs of segmented appendages (maxillae?) originating on the oral surface near the supposed position of the mouth. Eyes and ventral cephalic appendages mostly unknown.

Thoracic segments twice as wide as long,

EXPLANATION OF PLATE 67

FIG. *1–3*—*Ceratiocaris pusillus* Matthew. *1*, right lateral view of a complete carapace, G.S.C. Hypotype 13298, ×6; *2*, same as figure 1, ×3; *3*, left lateral view of a complete carapace, G.S.C. Hypotype 13298A, ×2½.

4—*Palaeocaris novascoticus* n. sp. View of three specimens, G.S.C. Paratypes 13324, ×4.

5—*Palaeocaris* sp. Dorsal view of a poorly preserved specimen, G.S.C. Hypotype 13315, ×2.

6,8—*Euproops* sp. Dorsal views of two prosomata, G.S.C. Hypotypes 13310 and 13311, ×2½.

7,9,10—*Euproops thompsoni* Raymond. *7*, interior view of a prosoma, G.S.C. Hypotype 13314, ×2½; *9*, dorsal view of a prosoma showing ocelli, dorsal pits and interophthalmic muscular markings, G.S.C. Hypotype 13312, ×2½; *10*, interior view of a prosoma showing interior projections of the dorsal pits and muscular markings, G.S.C. 13313, ×2½.

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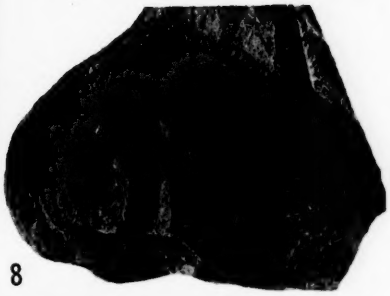

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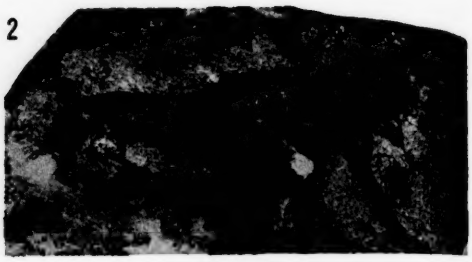
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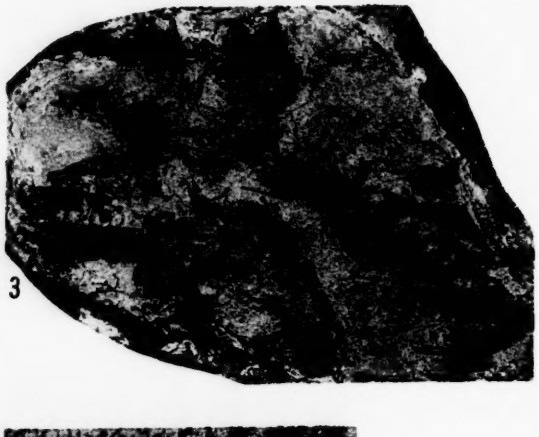
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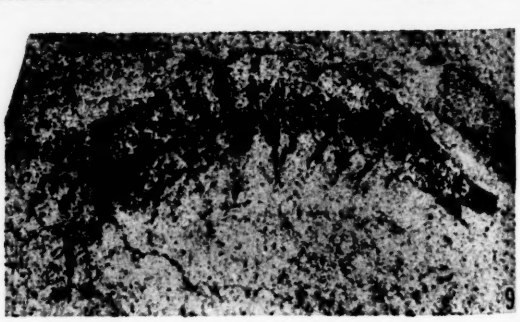
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each with a dorsal tergum, short lateral pleurae, and a pair of long uniramous limbs. Limbs equal to one-third the length of the body, each three-jointed, proximal segment the longest, non-chelate.

Abdominal segments tapering posteriorly, five anterior ones bearing long, posteriorly curved pleurae; twice as wide as long, and bearing a pair of short, three-jointed uniramous limbs; last abdominal segment slightly longer than wide, with no limbs, bearing the telson and uropods.

Telson twice as long as wide, tapering posteriorly, bluntly rounded, with three or four pairs of strong spines on the posterior margin. Uropods originating at the protopodite near the base of the telson, one and one-half times as long as the telson, finely setate along the lateral margins.

Remarks.—This species, although similar in size and shape to the type species, differs in several characteristics. *P. novascoticus* has a very short, strongly developed endopodite on the first antennae, a relatively long head shield, coarse spinose projections (not setate) on the posterior margin of the telson, and uropods substantially longer than the telson. *P. typus*, on the other hand, has a thinner endopodite on the first antennae, a shorter head shield, a setate telson, and uropods only slightly longer than the telson and separated near their proximal ends by a transverse division. *P. novascoticus* is of nearly the same age as *P. scoticus* Peach 1881 from the Lower Carboniferous of Scotland. *P. scoticus*, however, has a much more ornate telson.

Locality.—From an unknown depth in Nova Scotia Department of Mines bore hole number 530 (Report for 1927 [1928], p. 169–170), one mile south of Hillsboro, Inverness County, Nova Scotia, in strata of the upper Horton group, collected by W. A. Bell, 1927.

Types.—Holotype, G.S.C. 13316 (obverse and reverse): Paratypes, G.S.C. 13317–13324.

Subphylum CHELICERATA
Class MEROSTOMATA
Subclass XIPHOSURA
Order XIPHOSURIDA
Suborder LIMULINA
Superfamily EUPROOPACEA
Family EUPROOPIDAE
Genus EUPROOPS Meek 1867

Prestwichia Woodward 1867 (*non* Lubbock 1863)
Anthracopeltis Boulay 1880
Prestwichianella Woodward 1918

Type species.—*Bellinurus danae* Meek and Worthen 1865.

A systematic key to the Maritime species of this genus follows:

1. Cardiac lobe broad
   A. Prosoma nearly semi-circular (l/w:1/2)
      a. Ophthalmic spines short or absent ..... *E. thompsoni*
   B. Prosoma not semi-circular (l/w:1/2.5–3)
      a. Ophthalmic spines short ..... *E. danae*
      b. Ophthalmic spines as long or longer than genal spines ..... *E. amiae*
2. Cardiac lobe narrow
   A. Prosoma nearly semi-circular
      a. Ophthalmic spines unknown ..... *E.* sp.

EUPROOPS sp.
Pl. 67, fig. 6,8

Two prosomata exhibiting characteristics of this genus have been collected from beds of the Windsor group. They are too poorly preserved for specific identification. Only

EXPLANATION OF PLATE 68

FIG. *1–9*—*Palaeocaris novascoticus*, n. sp. *1,2*, observe and reverse oblique lateral views of a complete specimen, G.S.C. Holotype 13316, ×4; *3*, view of several specimens, G.S.C. Paratype 13317, ×4; *4*, right lateral view of four posterior abdominal segments and telson; note limbs on the three anterior segments, G.S.C. Paratype 13318, ×8; *5*, view of the antennary processes, G.S.C. Paratype 13319, ×8; *6*, dorsal view of a nearly complete specimen, G.S.C. Paratype 13320, ×8; *7*, dorsal view of a telson and uropods; note the posterior telson spines, G.S.C. Paratype 13321, ×8; *8*, anterior dorsal view of an incomplete specimen, G.S.C. Paratype 13322, ×4; *9*, left lateral view of a poorly preserved specimen, G.S.C. Paratype 13323, ×8.

portions of the head-shields, cardiac lobes, and posterior parts of the ophthalmic ridges are visible. Length/width ratios of these head shields are near those of *E. danae* (Meek and Worthen), however, the cardiac lobes appear narrower than in that species.

Locality.—G.S.C. locality 25648, Kentville Creek at Limestone Point on Pugwash Basin, Cumberland County, Nova Scotia, collected by H. M. Ami, 1899.

Types.—Hypotypes, G.S.C. 13310 13311.

EUPROOPS THOMPSONI Raymond 1944
Pl. 67, fig. 7,9,10

The description of this species has been inferred by Raymond (1944, p. 486) to agree in most respects with that of *E. danae* (Meek and Worthen). Specific differentiation is based mainly on the length/width ratio of the prosoma—that of *E. danae* being 1/2.5–3 and *E. thompsoni* ½. The prosoma of *E. thompsoni*, therefore, is more semicircular in outline than that of *E. danae*. Future work based on the measurement of numerous specimens from the type locality near Mazon Creek, Illinois, may show the existence of a continuous lineage intermediate between these two species.

Three well-preserved head shields showing interior and exterior views were obtained from strata of the lower Windsor group in association with a marine fauna (Bell, 1944, pl 38). The length/width ratios and lateral outlines of these prosomata are similar to those proposed by Raymond for this species. The specimens show cardiophthalmic structures not previously reported for this species.

Dorsal view.—The cardiophthalmic region occupies more than one-third of the prosomal surface (pl. 1, fig. 9). It is bounded by the slightly convex posterior margin and the continuous lateral ophthalmic ridges. These ridges, which do not appear to bear ophthalmic spines, extend forward from the posterior margin to the compound eyes, broadening where they curve to unite at the median line anterior to the cardiac lobe.

A well-defined anterior heart-shaped swelling is formed by the junction of the ophthalmic and cardiac ridges. This frontal node bears a pair of shallow, elongate depressions on either side of the median axis. These depressions appear to occupy the position of ocelli as demonstrated by other specimens of this genus.

The cardiac area tapers anteriorly and is divided by two pairs of axial furrows into three distinct lobes—posterior, intermediate, and anterior. These furrows are directed posteriorly from the lateral cardiac margins, not joining along the median line. The posterior cardiac lobe is about five times as wide as long, the intermediate lobe nearly square, and the anterior lobe 2½ to 3 times as long as wide.

The interophthalmic areas bear five pairs of muscular impressions. The two posterior pairs of impressions lie adjacent to the posterior and intermediate cardiac lobes, the three anterior pairs are adjacent to the anterior cardiac lobe but are discernible only near the ophthalmic ridges. A pair of small, deep pits are present on the anterior pair of interophthalmic impressions, one on either side and adjacent to the frontal lobe.

Ventral view.—Two specimens (pl. 1, fig. 7,10) show interior views of the prosoma. A broad doublure is present on the interior lateral and anterior margins. The ophthalmic and cardiac areas lie within the central depressed region of the prosoma. The ophthalmic ridges are indicated by deep furrows joined to the anterior end of the depressed cardiac lobe. Muscular markings on the interophthalmic areas are shown as shallow depressions separated from the cardiac lobe by a well-defined ridge and from each other by fainter ridges. A pair of bosses are present at the anterior ends of the marginal cardiac ridges, lying on either side of the anterior frontal lobe, in the positions of the dorsal pits.

Remarks.—To some extent lobation of the cardiac and interophthalmic areas suggests the anterior segmentation of specimens of this class (Størmer, 1955, p. P5). As indicated by the muscular impressions on *E. thompsoni*, the chelicerae and several (4 or 5) pairs of walking limbs were probably incorporated within the prosomal shield. The labrum and mouth may have been situated at the junctures of the anterior-intermediate and intermediate-posterior cardiac lobes respectively. The pair of small, deep pits on the anterior interophthalmic muscle impressions may represent points of additional

muscular attachment or the presence of accessory dorsal sensory organs.

Locality.—Near Wallace, Cumberland County, Nova Scotia, at the mouth of the brook intersecting the Wallace and North Shore roads, collected by W. A. Bell.

Types.—Hypotypes, G.S.C. 13312–13314.

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MANUSCRIPT RECEIVED SEPTEMBER 9, 1956

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 600–602, PL. 67, 1 TEXT-FIG., MAY 1957

A REDESCRIPTION OF *CERATIOCARIS PUSILLA* MATTHEW 1889[1]

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ABSTRACT—A redescription of the Upper? Silurian species *Ceratiocaris? pusilla* Matthew is possible from material obtained from the type locality near St. John, New Brunswick. The species is clearly shown to exhibit morphological characteristics of the genus *Ceratiocaris*.

INTRODUCTION

SPECIMENS of *Ceratiocaris pusilla* have only been reported from strata of presumed Upper Silurian age near Westfield Station, New Brunswick. The species was described by G. F. Matthew in 1889 and has been referred to by several subsequent workers. No attempt has been made since 1889 to re-examine the systematic position of the species. Several well preserved specimens showing details not previously known are in the collection of the Geological Survey of Canada. These specimens constitute the basis for the present redescription of the species.

ACKNOWLEDGMENTS

Thanks are expressed to the Geological Survey of Canada for permission to examine and photograph specimens from their collection, and to Dr. L. M. Cumming of the Geological Survey for making available to the author the material on which this paper is based. Casts of the type specimens were made available through the kind co-operation of Dr. M. A. Fritz of the Royal Ontario Museum of Zoology and Palaeontology.

LOCATION AND STRATIGRAPHIC POSITION

All reported specimens of this species have been obtained from an outcrop of fissile black shale one mile above the mouth of Cunningham Brook, about 14 miles northeast of St. John, New Brunswick (see Geological Survey of Canada, Preliminary Map 51–15). The shale occurs within the Jones Creek formation near its upper contact with the Long Reach formation of the Silurian Mascarene? group. These shales are jointed and cleave readily along three planes, one parallel with the bedding, the others dipping toward each other to intersect at about 45 degrees.

SYSTEMATIC POSITION

Doubt has existed as to the generic position of this species since its original description. Matthew (1889) questioned the inclusion of the species within the family Ceratiocaridae and later (1898) referred it to the family Rhinocaridae. In a letter to Prof. T. R. Jones (*see* Jones, 1900, p. 404) dated Nov. 5, 1897, Matthew stated, "I have referred *Ceratiocaris pusilla* to *Rhinocaris* as being the nearest genus, but it appears to have a fixed rostrum (attached to one valve), though possibly the suture may run through the apex of the shield." Later workers, following the original description, have referred the species to *Ceratiocaris*.

Specimens are commonly preserved as laterally compressed carbonaceous films showing little or no surface ornamentation. The exact relationship of the rostral process to the main part of the carapace has apparently led to the previous ambiguity of the generic assignment. Distinction between the genera *Ceratiocaris* and *Rhinocaris* depends largely on the identification of the rostrum as a separate lanceolate plate or a flattened prora continuous with the carapace (*see* Hall, 1888, p. lii–lviii). From examination of the more perfectly preserved material presently available it is apparent that the rostrum and carapace are not contiguous. The species is retained, therefore, within the family Ceratiocaridae.

[1] Published by permission of the Acting Deputy Minister, Department of Mines and Technical Surveys, Ottawa.

[2] Geologist, Geological Survey of Canada

SYSTEMATIC DESCRIPTION

CLASS CRUSTACEA

SUBCLASS MALACOSTRACA

ORDER PHYLLOCARIDA PACKARD 1879

FAMILY CERATIOCARIDAE SALTER

GENUS CERATIOCARIS MCCOY 1849

Type species.—*Ceratiocaris solenoides* McCoy 1849, by subsequent designation of S. A. Miller 1889, p. 537.

Ceratiocaris pusilla Matthew
Pl. 67, fig. 1–3

Ceratiocaris pusillus Matthew 1889, p. 56, pl. 4, fig. 9
Ceratiocaris pusillus Miller 1889, p. 537
Ceratiocaris pusilla Jones 1890, p. 64.
Ceratiocaris pusillus Vogdes 1893, p. 378
Rhinocaris pusilla Matthew 1898, *in* Jones, p. 344
Rhinocaris pusilla Matthew 1898, *in* Jones, p. 43
Rhinocaris pusilla Matthew 1900, *in* Jones, p. 404
Ceratiocaris pusilla Bassler 1915, p. 1390
Ceratiocaris pusillus Stetson 1928, p. 225
?Ceratiocaris pusilla van Straelen and Schmitz 1934, p. 63

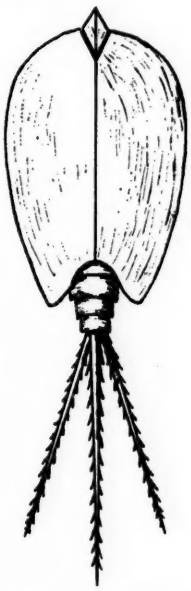
Description.—An emended description is as follows:

Carapace bivalved, with faint longitudinal striae; horseshoe-shaped in dorsal view, elliptical to oblong in lateral view; anterior broadly rounded, incised at mid-dorsum about 1/7 the length of the carapace; anterior margin continuous with moderately convex ventral margin, postero-lateral angles blunt, posterior smoothly notched; valves united along faint mid-dorsal ridge extending the length of the carapace; dorsum straight to arched in lateral view.

Rostrum faintly striated, angular to diamond-shaped, with a medial longitudinal ridge aligned with the dorsal ridge of the carapace; fitted smoothly into the anterodorsal carapace incision; apex extending anterior to carapace on mid-dorsum; deflected ventrally; about 1 mm. in length.

Three or four abdominal segments exsert; tapering posteriorly; telson long and slender, with two lateral stylets, all bearing numerous minute lateral spines.

		A	B
Carapace	length	11.7 mm.	15.2 mm.
	width	3.6 mm.	4.2 mm.
Abdomen	length	3.1 mm.	2.4 mm.
	width	1.3 mm.	1.0 mm.



TEXT-FIG. *1*—Restoration of *Ceratiocaris pusilla* ×3.

Remarks.—Of the many specimens examined only one has been found exhibiting a dorsal view of the carapace, the median dorsal ridge, and the separate lanceolate rostrum. This specimen is too poorly preserved to be photographed. All other specimens are preserved as laterally compressed carbonaceous films, two of which are shown on the accompanying plate.

This species appears to agree most nearly with *C. inornatus* Salter 1852 (*in* Sedgwick and McCoy 1852, p. 137, pl. IE, fig. 4). The specimen shown by McCoy, however, bears an anterodorsal "eye spot" and is much larger than the New Brunswick species.

Type.—Holotype, Royal Ontario Museum of Zoology and Palaeontology, Toronto, Ontario, No. 22701; Hypotypes, Geological Survey of Canada, Ottawa, Ontario, Nos. 13298 and 13298A.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 603–606, PL. 69, 2 TEXT-FIG., MAY 1957

RELATIONSHIPS BETWEEN *ACANTHOCLADIA GUADALUPENSIS* AND *SOLENOPORA TEXANA* AND THE BRYOZOAN-ALGAL CONSORTIUM HYPOTHESIS

J. KEITH RIGBY

ABSTRACT—The bryozoan *Acanthocladia guadalupensis* Girty and the alga *Solenopora texana* Johnson consistently occur together in many thin sections of Permian limestone from Texas and New Mexico. *Solenopora* forms the entire minutely cellular reverse side of *Acanthocladia* and consists of small radiating unchambered tubules. These tubules ultimately connect at their bases with a "canal" system which surrounds the zooecial wall of the bryozoan. This close interrelationship between bryozoan and alga indicates that the pinnate *Acanthocladia* probably is an algal bryozoan symbiot.

INTRODUCTION

IN THE process of studying fabrics of many exposures of reef limestone in the Permian rocks of West Texas. it became apparent that the bryozoan *Acanthocladia guadalupensis* Girty nearly always occurred in association with the alga *Solenopora texana* Johnson. This relationship suggests an algal bryozoan consortium such as that described by Condra & Elias (1944) for *Archimedes*.

Many thin sections were studied during the course of the investigation, but for the present work the best results have been obtained from cellulose acetate peels. Peels were prepared using the solution and method described by Darrah (1936).

GENERAL OBSERVATIONS

The bryozoan *Acanthocladia guadalupensis* is one of the most abundant and important rock-forming bryozoans in the reef tracts of the Permian of West Texas. It is a long ranging species, and can be found abundantly in rocks from Wolfcampian to highest Capitanian reef-rock exposures. It forms pinnate branches and characteristically grows in small clumps. Main branches range from 1 to 2 mm. in diameter and the smaller diverging branchlets range up to 1 mm. in diameter. Girty (1908, p. 149–152) described the species in some detail. He observed that the test increased in size with age of the colony, mainly by addition of testaceous material on the nonporous side of the colony. Girty observed that this testaceous material is finely tubular, with tubules generally arranged normal to the outer surface.

Condra & Elias (1944, p. 48) pointed out that the encrusting material which enlarges *Acanthocladia* fronds in certain species has much in common with *Archeolithothamnion*, a Cretaceous and early Tertiary encrusting red alga. Their observations were supported, unknowingly it seems, by J. H. Johnson when he described this tubular structure as *Solenopora texana* Johnson (1951, p. 23). The mutual occurrence of the two forms is conclusively shown in the numerous thin sections and acetate peels of Permian rocks in which the structure described as *Solenopora* always occurs intergrown and "encrusting" the bryozoan zooecia. Conversely, *Acanthocladia* never occurs in my material without the enlarging tubular material on the non-porous side of the frond.

Johnson (1951, p. 23) described *Solenopora texana* as follows:

> Thallus encrusting to nodular; 0.5 to 6.2 mm. thick. Composed of long, slender tubular cells having a diameter of 0.006 to 0.013 mm. and forming irregular growth zones. No cross partitions visible. Cells rather widely spaced with thick coating of algal dust between. No suggestions of sporangia.
>
> [Some specimens] appear to form nodular or hemispherical masses, others encrust bryozoan shreds, and others foreign material. In general appearance of the tissue it somewhat suggests an encrusting *Lithothamnium*, but lacks the well defined cross partitions of the latter. However, it resembles a *Lithothamnium* more than any other Paleozoic *Solenopora* known to the writer.

OBSERVATIONS ON MICROSTRUCTURE

Two types of algal cells or "canals" have been recognized in examples of *Acanthocladia guadalupensis*. These are: (1) an easily observed radiating canal or tubule system described as *Solenopora texana* Johnson, and (2) a less well developed but very persistent

canal which more or less surrounds the zooecial wall. Additional minute canals or perforations pierce the lamellar zooecial wall and connect the zooecia to the radiating tubule system.

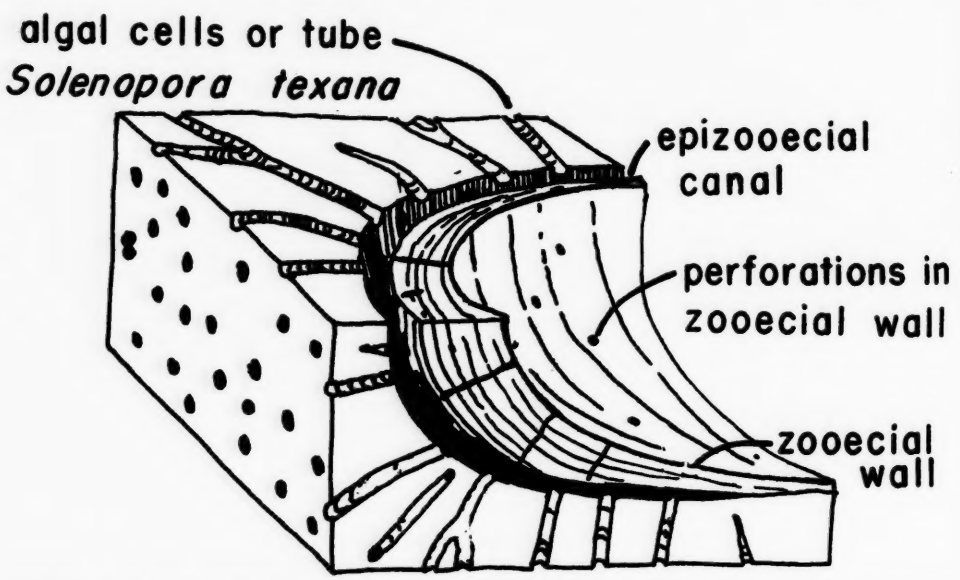
Illustrations of type specimens of *Solenopora texana* (Johnson, 1951, pl. 6, fig. 4,5) show the radiating pattern of the algal cells and their distribution relative to the bryozoan zooecia. These tubules are commonly 0.006 to 0.015 mm. in diameter in the writer's material and are frequently as much as 2 mm. long. They are essentially uniform in diameter and are circular to suboval in cross section (text-fig. 2–4). Tubules are commonly randomly spaced from 0.01 to 0.05 mm. apart, and are separated by dense granular material referred to as algal dust by Johnson. Partitions are not present throughout the length of any tubule, indicating a continuous connection between the radiating tubules and the rest of the cell or canal system.

Tubules branch at various intervals from 0.1 to 0.5, mm. but rarely branch more than three or four times between the zooecial wall and the periphery of the mass (text-fig. 2–3). They are seen to cross at certain points (text-fig. 2–1,2), particularly in the immediate vicinity of the zooecial wall. Crossing is less common at some distance from the zooecial wall and was not observed in the outer third of the mass.

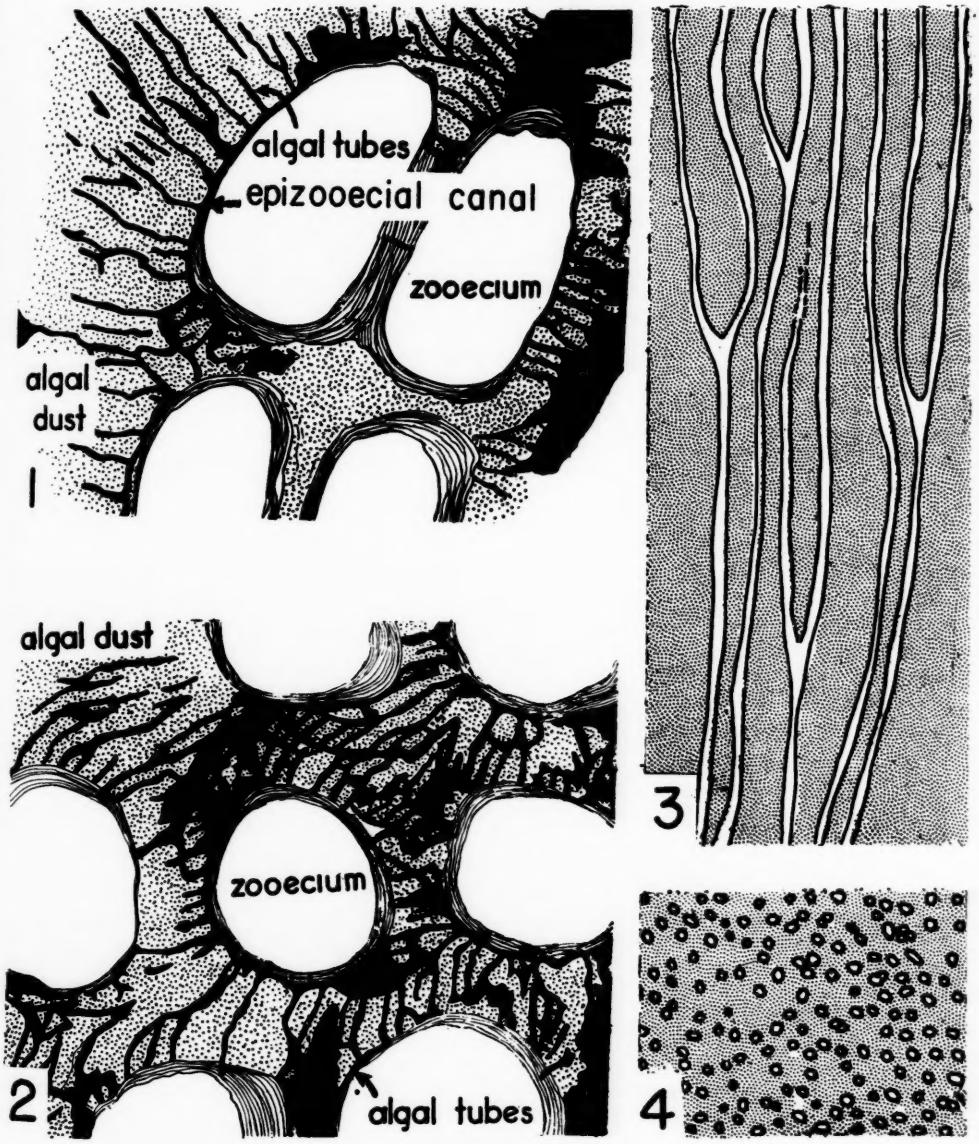
Radiating algal cells common in *Acanthocladia* are possibly similar to so-called canals observed in other bryozoans. Ulrich (1890, p. 53) reported very delicate tubules which penetrate the finely laminated stony deposit over the front and back of *Lyropora*. Similar tubules have been reported by Shulga (1931, p. 77–79) from a branch of *Lyrocladia*.

The small radiating algal cells usually connect to a distinctly different canal or algal layer which occurs immediately outside the laminated zooecial wall (pl. 69, fig. 1–2; text-fig. 2–1,2). The latter canal is termed the epizooecial canal in contrast to the tubules which diverge more or less perpendicularly from the zooecial wall. The epizooecial canal surrounds at least one half of each zooecium and is a common connecting point for all the radiating canals or tubules. The canal is most commonly developed on the upper and outer side of the zooecium, on the side of the zooecium where the zooecial wall is thinnest. The epizooecial canal is commonly slightly thinner than the average diameter of the radiating cells and averages approximately 0.01 mm. thick.

A complex system of interwoven and interconnected canals is developed at either



TEXT-FIG. 1—Schematic diagram of portion of *Acanthocladia* branch, showing relationship of bryozoan zooecium to epizooecial canal, radiating algal tubules, and minute canals which penetrate zooecial walls.



TEXT-FIG. 2

1,2—*Solenopora texana* Johnson and *Acanthocladia guadalupensis* Girty. Line drawing of photomicrograph from cellulose peels, showing relationship of algal tubes (*Solenopora texana*) to algal dust, epizooecial canal, and bryozoan (*Acanthocaldia guadalupensis*). Locality 927, upper limestone, Leonard formation, Word Ranch, Glass Mountains Texas. ×157.

3—*Solenopora texana* Johnson. Sketch, showing tubules separated by algal dust, characteristic branching of tubules, and lack of cross partitions in tubules. Locality 927, upper limestone, Leonard formation, Word Ranch, Glass Mountains, Texas. ×173.

4—*Solenopora texana* Johnson. Bleached line drawing of photomicrograph, showing cross-sections of algal tubules and their distribution in algal dust. Locality 927, upper limestone Leonard formation, Glass Mountains, Texas. ×157.

extremity of the epizooecial canal (text-fig. 2–1,2). It is shown as a large solid black area on the accompanying drawings, and appears as a dominantly light gray area in the photographs (pl. 69, fig. 1,2). It is not known whether these complex-appearing

areas were voids or were partially filled by spongy calcareous material during the life of the colony. Such spongy material would be difficult to see under the microscope.

Seemingly identical canals have been previously described by Shulga (1931, p. 78) in fenestellid bryozoans. She concluded that there are capillary canals which extend along the branches in close proximity to the zooecia and encircle each zooecium on all sides and pass over its roof. According to Condra & Elias (1951, p. 27), Likharev has shown a light gray layer at the base of zooecia of *Fenestella retiformis*. This light gray layer is possibly the epizooecial canal observed in *Acanthocladia*. The writer has observed similar canals in other Paleozoic fenestellids, particularly in some shown the writer by Heinrich Toots, and in other fenestellids seen in peels and thin sections prepared by the writer from Leonardian material from the Glass Mountains, Texas.

Several minute canals penetrate the lamellar zooecial wall and connect the zooecium to the surrounding epizooecial canal. These have a diameter which ranges from approximately 0.001 to 0.005 mm. Examples can be seen in the central zooecium and the right central zooecium of text-fig. 2–2. It would thus appear that there was common access from the zooecium through the canals or cells to the reverse side of the *Acanthocladia* frond. Similar connecting pores were suggested by Shulga (1941, p. 34–34) as occurring in the thin zooecial walls of *Lyrocladia* between zooecia and special capillary tubes which surround the zooecia.

CONCLUSIONS

Until Johnson (1951) proposed an algal origin for the tubule system developed on the reverse side of *Acanthocladia* branches, little thought had been given to the system's possible non-bryozoan origin. Shulga (1941, Ulrich (1890), and Condra & Elias (1944) have all considered the possible relation of the tubules to the bryozoan zooid. Condra & Elias (1944, p. 27) doubted the existence of such a complicated system of canals and stated that the conclusions of Shulga were mainly of inference rather than observation. The present work substantiates Shulga's conclusions concerning the complexity of the canal system, but not of the bryozoan origin for the system. Evidence now indicates an algal origin rather than a bryozoan origin for the tubule or cell system. *Acanthocladia guadalupensis* seems to be an algal-bryozoan intergrowth.

Although indicative, the evidence is not overwhelming concerning the algal orgin of the tubules. Since the tubules are intimately associated with the bryozoan and lack distinctive tabulae or cross partitions characteristic of *Lithothamnium*, additional study may be necessary to ascertain their true origin. If the tubule system is not algal, then it must have been a functional part of the bryozoan colony. It has been suggested that such a system as described above may have been useful in removing excess calcareous material from the bryozoan zooid and in transporting this material to the outside for deposition.

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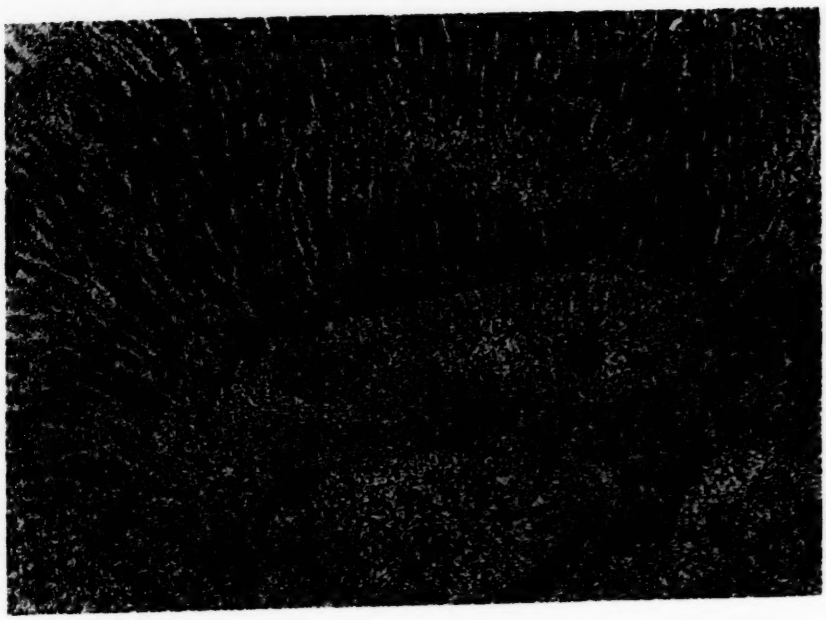
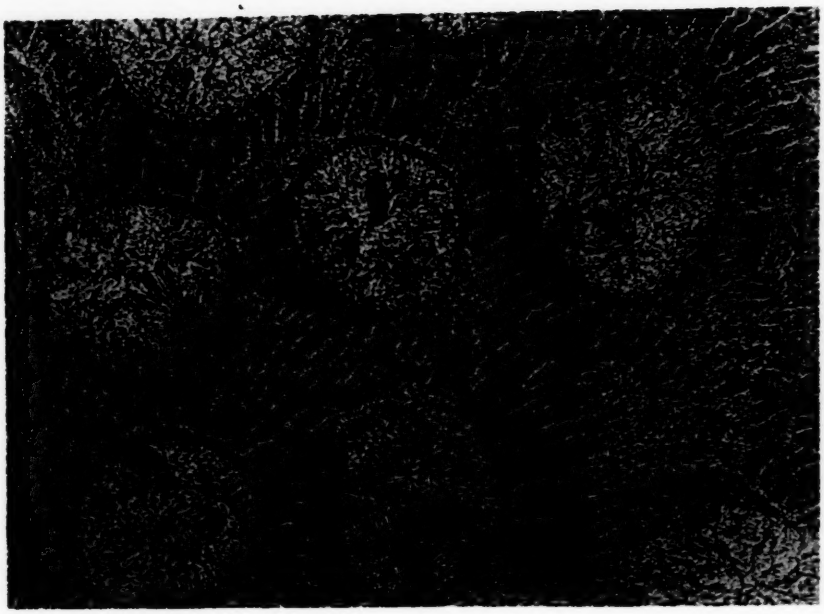
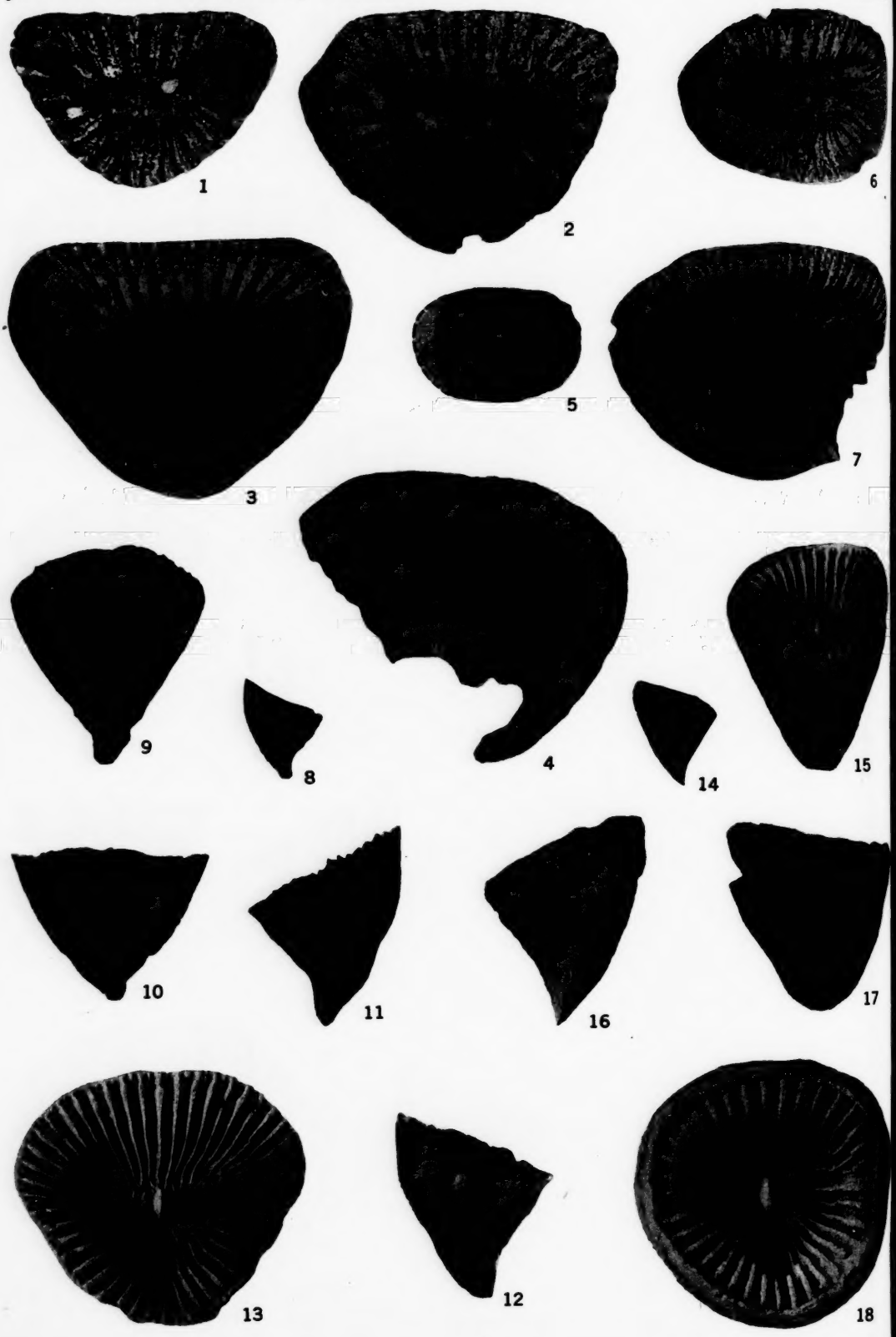
MANUSCRIPT RECEIVED MAY 5, 1956

EXPLANATION OF PLATE 69

FIG. *1,2*—*Solenopora texana* Johnson and *Acanthocladia guadalupensis* Girty. Photomicrographs of cellulose peels showing relationships of algal cells (light gray radiating tubules) and bryozoan zooecia. Note also the epizooecial canals developed immediately outside the zooecial walls at the termini of the algal cells. Locality 927, upper Leonard limestone, Word Ranch, Glass Mountains, Texas.



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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 607–615, PL. 70, MAY 1957

BIGHORNIA, A NEW ORDOVICIAN CORAL GENUS[1]

HELEN DUNCAN
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ABSTRACT—The new genus *Bighornia* is erected for typically columellate small subcalceoloid horn corals that are widely distributed in the Upper Ordovician rocks of western North America and the Arctic Archipelago. Besides the genotype, *Bighornia parva*, n. sp., from the uppermost beds of the Bighorn dolomite in the Bighorn Mountains, Wyoming, the genus includes: *Holophragma anticonvexa* Okulitch, *?Holophragma scheii* Cox, *Lindströmia solearis* Ladd, *Streptelasma* aff. *breve* Ulrich of Troedsson, *S. integriseptatum* Parks, *S. patellum* Wilson, and possibly *S.? latum* Teichert and *S.? oppletum* Teichert. *Bighornia* is easily recognized because of its distinctive shape and columella and has proved to be a useful guide to rocks of Bighorn age in western United States.

INTRODUCTION

SEVERAL authors have described small subcalceoloid columellate corals from the Ordovician rocks of North America. Species were placed orginally in *Streptelasma*, *Lindströmia*, or *Holophragma*. It was not recognized that most of these forms were congeneric or that the various generic assignments were not sound. Except for one from the Maquoketa shale of Iowa, all the described species came from Arctic America and western Canada. It has been known for many years, however, that similar corals occur in the Bighorn dolomite of Wyoming and in the Fremont limestone of Colorado. Recent work by the writer and associates on the Ordovician rocks and faunas of the Western States has shown that corals of this type are widely distributed in other formations of Late Ordovician age.

Most species of this coral have a distinctive form and a conspicuous axial structure. These features make the genus one of the most easily identified and stratigraphically useful fossils in Late Ordovician faunas of the West. The writer has in progress a systematic study of species belonging to the genus with an interpretation of the phylogeny and relationshps of the taxon with other Ordovician streptelasmatid corals, but it probably will be several years before this work is completed. For a good many years we have been identifying specimens of this coral as "*Holophragma*" (see Duncan, 1956, pl. 22, fig. 1a–1c). Because it is undesirable to continue using such misleading nomenclature in our stratigraphic reports, a diagnosis of the genus *Bighornia* and a description of the type species were ex-

[1] Publication authorized by the Director, U. S. Geological Survey.

EXPLANATION OF PLATE 70

All specimens from the uppermost beds of the Bighorn dolomite, south fork of Rock Creek, Bighorn Mountains, Wyoming.

FIG. *1–18—Bighornia parva*, n. sp. *1–4*, serial sections of paratype, ×5, USNM 127576, USGS locality 1362-CO. This specimen shows evidence of boring organisms. *5–7*, serial sections of another paratype, ×5, USNM 127577, USGS locality 68-SD. An early neanic stage in which all septa including the cardinal extend to the axial region and fill the lumen is illustrated in fig. 5. *8–13*, Holotype, USNM 127574, USGS locality 1362-CO; *8*, alar view, ×1; *9*, cardinal side of corallum with oblique view of calyx, ×2; *10*, convex counter side showing marked flatness of upper part of corallum and evidence of boring organisms, ×2; *11*, alar view, ×2; *12*, longitudinal section along median fracture in the cardinal-counter plane showing the compact lathe-like columella, ×2; *13*, calyx, ×3. *14–18*, Paratype, USNM 124801, USGS locality 68-SD; *14*, alar view, ×1; *15*, cardinal side of corallum showing calyx obliquely, ×2; *16*, alar view showing carination along trace of alar septum, ×2; *17*, counter side of corallum, ×2 *18*, calyx, ×3.

tracted from the longer manuscript for publication in advance of the detailed study.

Family STREPTELASMATIDAE Nicholson, 1889 (as Streptelasmidae)
Genus BIGHORNIA, n. gen.

Diagnosis.—Solitary corals with streptelasmatid septal structure; counter side of corallum convex, always flattened in the apical region; angulation generally developed along traces of alar septa in neanic stages; epitheca marked by faint longitudinal ridges and grooves, fine transverse striae, and, in some species, relatively weak rugae; conspicuously shortened cardinal septum in well-defined fossula on concave side of corallum; typically with a lathe-like terminally rounded columella formed primarily by thickened axial end of counter septum and arising from a *Grewingkia*-like axial structure.

Type species.—*Bighornia parva*, n. sp.

Discussion.—The genus is interpreted on a number of described and undescribed species as well as on the genotype. In shape of corallum and development of the axial structure, a few species differ conspicuously from the more typical section of the genus; but intermediate forms provide evidence that suggests these aberrant species were adapted for restricted environments.

Septal microstructure in *Bighornia* is similar to that in other Ordovician streptelasmatid corals (see Wang, 1950, p. 213, pl. 5, fig. 22,23). The septa and columella are fibrous and not clearly trabeculate, and the axial edges of the septa are finely denticulate. In most forms the major septa are conspicuously dilated and completely fill the apical part of the corallum. Alternating minor septa coalesce with the majors to form a peripheral stereozone in ephebic stages. Except the cardinal fossula, interseptal loculi in most species are much reduced even in ephebic stages. Tabulae are developed in the ephebic stages of larger species, which tend to have less dilated septa, but are uncommon in smaller forms.

Bighornia differs from all other described Ordovician streptelasmatid genera in having coralla convexly curved on the counter side and in developing a short cardinal septum at an early stage. The other Ordovician horn coral genera are conical, convex on the cardinal side, or erratically curved; and they characteristically have a thin cardinal septum that is as long as the other major septa.

The known species of *Bighornia* are small or medium sized in comparison with associated forms of *Streptelasma* and *Grewingkia*, some of which attain lengths of 80 to 100 mm. Previously described species of *Bighornia* are mostly subcalceoloid in form, the convex counter side being distinctly flattened. Species originally assigned to *Holophragma* were obviously so identified because of their calceoloid coralla. The form of the ephebic corallum, however, seems to be a variable character that has specific rather than generic significance. One species, at least, is almost cuneate; others tend to be trochoid or ceratoid; and some are flabellate. Depending on the stage of development and the species, transverse sections through the base of the calyx are subtriangular, oval or crescentic (elongate in the alar plane), or round. Transverse sections through neanic stages of all forms are subtriangular or elongate oval owing to apical flattening of the counter side, a feature that is interpreted to have been genetically controlled.

Some examples of *Bighornia* were originally identified as *Lindstrōmia* because they had prominent columellae. Although a fairly prominent columella is one of the most distinctive features in the Bighornias described so far, a genuine columella is not regarded as a fundamental generic character. Some flabellate forms with crescentic transverse sections commonly do not have a columella; and some of the earliest species have a slightly raised axial structure in which the axial ends of the major septa dilate, anastomose, and break up to some extent, thereby forming knots on the floor of the calyx. Axial structures of this type are developed in many of the later Streptelasmas and culminate in *Grewingkia*. In *Bighornia*, however, the axial structure normally is dominated by the counter septum; whereas in other streptelasmatid genera, the counter septum generally loses its identity in the axial complex.

Bighornia is a member of the group of angulate streptelasmatid corals that are a conspicuous element in Late Ordovician Arctic faunas (Duncan, 1956, p. 218, pl. 22).

Except *Bighornia*, the corals of this group are most strongly angulate along the trace of the cardinal septum. In many species angulation developed also along the alar septa, and a very few forms tend to be angular along the counter septum as well. All the angulate Streptelasmas and Grewingkias have coralla that are convex on the cardinal side. *Bighornia* shows no indication of carination along the cardinal or the counter septa; but in nearly all specimens studied, alar angulation is a characteristic feature of neanic growth stages and persists into ephebic stages in some species.

Comparison with other genera.—Bighornia is readily differentiated from the four genera—*Streptelasma*, *Lindströmia*, *Holophragma*, and *Coelostylis*—in which previously described species were placed.

Streptelasma Hall (1847, p. 17), as interpreted by most authors, contains a considerable variety of forms. Both solitary and compound species have been referred to the genus, and asexual increase is fairly common in the early species. Solitary coralla are generally trochoid or ceratoid; some are conical and not curved, others are erratically and inconsistently curved, and the more advanced species, both angulate and nonangulate, are consistently convex on the cardinal side. In all species, the cardinal septum is as long as the other major septa; it is commonly thinner than the others but is never aborted. Axial structures are essentially lacking in the earliest forms and are not present in some of the later solitary and colonial species. However, moderately to conspicuously raised axial structures formed by the distrupted and twisted axial ends of the major septa and incomplete domed tabulae) occur in many of the species that currently are included in *Streptelasma*—the forms with broad, elaborate, elevated axial structures should be transferred to *Grewingkia* Dybowski (1873, p. 128–129). A columella like that of *Bighornia* was not developed in *Streptelasma* or *Grewingkia*, and only rarely can the counter septum be distinguished from other septa in the axial structures of species that belong to these genera.

A good many solitary corals with conspicuous axial columns originally were identified as *Lindströmia* Nicholson and Thomson (1876, p. 150). The generic name was used for Permian as well as for Ordovician species, but it has been avoided in recent systematic work. The genotype, *L. columnaris* Nicholson and Thomson (1876, p. 150; Nicholson and Etheridge, 1878, p. 84), is said to be from the Devonian of North America. Lang, Smith, and Thomas (1940, p. 77) thought this species might belong to *Metriophyllum* Milne Edwards and Haime (1850, p. lxix); Stumm (1949, p. 7–8) observed that illustrations published by Nicholson and Etheridge suggest that the coral is "very similar to *Stereolasma*" Simpson (1900, p. 205). In any event, the authors of *Lindströmia* state that "the corallum is simple and conical" and that the septa "meet in the centre of the visceral chamber, where they coalesce to a greater or less extent, and form a strong twisted pseudocolumella" (Nicholson and Thomson, 1876, p. 150). The transverse section of *L. columnaris* illustrated by Nicholson and Etheridge (1878, p. 84, fig. 4b′) shows no fossula, and the major septa meet axially and are reinforced with sclerenchyme.

Holophragma Lindström (1896, p. 35–36) is based on a species (*Hallia calceoloides* Lindström, 1866, p. 289, in part; Lindström, 1896, p. 36–37) having a markedly calceoloid corallum. Unlike *Bighornia*, the cardinal side is flattened and convexly curved. The cardinal septum tends to be the longest and most prominent of the major septa; there is no open cardinal fossula and no columella. The counter septum is no longer than other major septa in the counter quadrants. In some specimens, several long cardinal lateral septa coalesce axially to form slightly elevated callosities on the floor of the calyx, but these deposits bear no resemblance to a streptelasmatid axial structure or to a columella. Lecompte (1952, p. 465) regarded *Holophragma* as a calceoloid derivative of *Pycnactis* Ryder (1926, p. 386). In this case, I believe that the calceoloid form is of specific rather than generic significance and that the name *Pycnactis* Ryder is a junior synonym of *Holophragma* Lindström.

Hill (1951, p. 18) doubtfully referred to *Coelostylis* Lindström (1880, p. 34) a species —*Streptelasma patellum* Wilson—that is here interpreted to belong to *Bighornia*.

Also, *Streptelasma? oppletum* Teichert, which Hill (1951, p. 17) assigned with question to *Coelostylis*, belongs either to *Bighornia* or to a closely related genus. According to Lindström's description, the genotype, *Coelostylis törnquisti* Lindström (1880, p. 34), has an erect conical corallum with a longitudinally ribbed epitheca. The structure called a columella is described as prominent and pointed and as having a vesicular structure. The only illustration published is a longitudinal section (Lindström, 1880, pl. 1, fig. 11) that does not help much for interpretation of the genus. The genotype is recorded as coming from the *Chasmops* limestone and is therefore Ordovician. Presumbably this coral is a streptelasmatid with an axial structure that is more prominent than those ordinarily developed in Streptelasmas of Middle Ordovician age. I have seen several examples of corals from the Ordovician of America that differ from typical *Streptelasma* only in possessing a styliform axial structure. It seems likely that the name *Coelostylis* may be applicable for this group. In any event, Lindström had studied the calceoloid corals extensively and no doubt would have noticed and commented on flattening and curvature of the corallum had such features been developed in *Coelostylis*. From the statements made about the form of the corallum and the vesicular structure of the "columella," it is highly improbable that Lindström was dealing with a species that would fall within the limits of *Bighornia*.

Described species referable to Bighornia.—The following species are here assigned to the new genus:

Holophragma anticonvexa Okulitch (1943, p. 68–69, pl. 1, fig. 11,12).
Streptelasma aff. *breve* Ulrich (Troedsson, 1929, p. 109, pl. 26, fig. 6,7).
Streptelasma integriseptatum Parks (1915, p. 13–15, pl. 5, fig. 1–3).
Streptelasma cf. *integriseptatum* Parks (Stearn, 1956, p. 88–89).
Streptelasma patellum Wilson (1926, p. 13, pl. 2, fig. 1).
?Holophragma scheii Cox (1937, p. 15–17, pl. 2, fig. 14–16).
Lindströmia solearis Ladd (1929, p. 397–399, pl. 4, fig. 6–12).

Two other species possibly belong in *Bighornia*, but the descriptions do not indicate whether the corals are flattened apically and the axial structures are not exactly typical. These species may be more closely related to an undescribed genus that occurs in the *Fusispira* zone of the Prosser cherty member of the Galena dolomite.

Streptelasma? latum Teichert (1937, p. 52–53, pl. 2, fig. 3,4,9).
Streptelasma? oppletum Teichert (1937, p. 51–52, pl. 2, fig. 6–8, pl. 3, fig. 1–4).

All species listed were based on very meager material. The original descriptions indicate that a maximum of four specimens were available for some of the species, and others were based on one or two specimens. In some instances the specimens were incomplete; in others, they were silicified and not suitable for sectioning. Teichert and Okulitch compared their species with *?Holophragma scheii* Cox, but authors of the other species apparently were unaware that related forms had been described. Consequently, most of the species are not sufficiently well characterized nor illustrated for evaluation, and I think that in some instances the specimens included in a single species do not all belong to the same specific category.

So far as possible, the previously described species have been interpreted in accordance with concepts developed through study of more extensive suites of specimens. Much of the material available is dolomitized or silicified and not satisfactory for investigation of the microstructure of septa, axial structure, and wall of the corallum. In spite of the poor quality of preservation, this material is valuable because it represents populations from different stratigraphic levels and a number of localities. Individual suites furnished data on the amount of variation that should be allowed within a species and were of great help in determining what characters were constant enough to be used in discrimination of species. As viewed at present, these characters are: size and shape of ephebic corallum; number of major septa present in the ephebic stage; length and development of the minor septa; tabulation; and nature of the axial structure.

Material available for the description of *Bighornia parva* is not so abundant as that for some the silicified and dolomitized populations. In erecting a new coral genus, however, it is highly desirable that the type species be based on specimens that provide information on the microstructure of various deposits in the corallum. The red shale at the

top of the Bighorn dolomite on the south fork of Rock Creek in the Bighorn Mountains has furnished three species of *Bighornia* preserved in a calcareous state. The one containing the most perfectly preserved specimens was chosen as genotype and is here described as the new species *Bighornia parva.*

Geologic range of Bighornia.—The most primitive species (undescribed) known at present occurs in the Kinnikinic quartzite and the basal strata of the Bighorn dolomite. Specimens of *Bighornia* have been found in the Bighorn dolomite at many localities, some of which are in the lower part of the formation and others in the Leigh dolomite member. In the United States, the genus is known also from the Saturday Mountain formation of central Idaho, the Fish Haven dolomite of Idaho and Utah, the Fremont limestone of Colorado, the Hanson Creek formation of Nevada, the Ely Springs dolomite of Nevada and California, the Montoya limestone of Texas, and the Maquoketa shale of Iowa and Minnesota. All these formations are considered to be Upper Ordovician by the U. S. Geological Survey.

In Canada and the Arctic islands, *Bighornia* is known from the Beaverfoot formation of British Columbia; the Selkirk limestone, the Shamattawa limestone, the Stonewall formation, and the Stony Mountain formation of Manitoba; the Ordovician of Ellesmereland; and the Cape Calhoun series of Washington Land (Greenland). Species described by Teichert from the Ordovician of Melville Peninsula, Iglukik Island, and Cockburn Land (Baffin Island) belong either to *Bighornia* or to a closely related genus. Most of the occurrences in western Canada are in formations definitely regarded as Upper Ordovician. The stratigraphic position of material collected in the Arctic islands is somewhat uncertain. Some geologists have argued that the fossil assemblages were of Trenton age; others, that they were Richmond; and it is highly probable that the so-called faunas are mixtures from several zones. In any event, there is no good evidence that the Arctic Bighornias came from Middle rather than from Upper Ordovician rocks.

So far as I have been able to ascertain from the literature, no species referable to *Bighornia* have been described from the Ordovician of northern Europe and Asia. It is expected that the genus eventually will be recognized there, however, because the Late Ordovician coral faunas of the Baltic region (Lyckholm-Borkholm) and the lower part of the Podkamennaya Tunguska River in Siberia (Ivanova, Soshhina, Astrova, & Ivanova, 1955, p. 182–183) have much in common with American Arctic faunas.

The genus has not been found in the type Trenton of New York State, and no corals so far described and illustrated from rocks of certain Trenton age in eastern North America seem to have the combination of characters diagnostic of *Bighornia.* In the Ordovician of the Mississippi Valley region, *Bighornia* has been identified only in the Maquoketa shale, a formation of Richmond age. So far as is known, the genus does not occur in the underlying Galena dolomite, but the *Fusispira* zone of the Prosser member of the Galena contains an undescribed noncolumellate coral that could be interpreted as a link between typical Trenton *Streptelasmaea* and *Bighorn.* From information available on the evolutionary development of Middle Ordovician horn corals, it seems unlikely that a form so stable in its fundamental characters and so divergent from *Streptelasma* (*sensu stricto*) could have differentiated from the ancestral stock before Late Ordovician time.

BIGHORNIA PARVA, n. sp.
Pl. 70, fig. 1–18

Diagnosis.—Small subcalceoloid *Bighornia* with a prominent columella; 36 to 46 major septa (average, 40) in ephebic stages; minor septa confined to peripheral stereozone, very weak or absent in calyx.

Description of types.—The holotype (pl. 70, fig. 8–13) is 17 mm. in maximum length.[2] The convex counter side is distinctly flattened, but alar angulation is inconspicuous. The apex is slightly pedunculate. Septal grooves and interseptal ridges are less prominent than the transverse striae and faint rugae of the epitheca. The calyx has a subtriangular outline and is slightly more than 3 mm. deep; at the rim it measures 13.3 mm. in the cardinal-counter plane and 15.7 in

[2] The maximum length of coralla was measured with calipers diagonally from the apex to the rim of the calyx on the counter side.

the alar plane. There are 46 major septa in the upper part of the calyx, the two latest counter laterals being very short, Minor septa are suggested by faint ridges alternating with the major septa on the counter side of the calyx. The lathe-like columella measures 1.25 mm. in the cardinal-counter plane and is about 0.5 mm. thick; it extends upward 3 mm. on the fossular side and 1 mm. on the counter side. The first counter lateral septa appear to join the counter septum on the floor of the calyx and to contribute to the columella; and the axial ends of several additional neighboring counter lateral septa anastomose to form a slightly raised, fluted and nodose axial structure that is dominated by the columella. Owing to the pinnate arrangement of the septa, alar pseudofossulae are a conspicuous feature of the calyx. The cardinal fossula is deep and its sides are essentially parallel until it flares out axially around the base of the columella. The holotype was not sectioned, but a median fracture through the corallum showed septa so dilated that interseptal loculi, except the cardinal fossula, are essentially obliterated in the apical part of the corallum. Tabulae seem to be absent.

One paratype (pl. 70, fig. 14–18) has a maximum length of 17.8 mm. The apical part of the corallum is markedly flattened on the counter side, and carinae mark the trace of the alar septa. Angulation disappears in the upper part of the corallum so that the rim of the calyx is nearly circular in outline, measuring 14 mm. in the cardinal-counter plane and 15 mm. in the alar plane. The apex is blunt. An impressed area (about 3 mm. by 3 mm.) occurs at the tip of the coral on the cardinal side. The epitheca is marked by faint longitudinal grooves and ridges, transverse striae, and inconspicuous rugae. Along one growth level in the upper part of the corallum, deposition of skeletal material was evidently interrupted, because the thecal deposits in the vicinity of the alar and cardinal septa are contracted immediately above this line. Major septa number 38, the latest counter laterals being mere denticulations at the calyx rim, which is much thickened in this specimen. Minor septa are barely suggested by faint ridges on the counter side of the calyx. The columella resembles that of the holotype, but it arises from a lower and less nodose axial callosity formed by the dilated ends of most of the major septa. Alar pseudofossulae are less conspicuous than in the holotype, but the cardinal fossula is similar. This paratype has not been sectioned.

An unfigured paratype (USNM 127575) is a specimen with an incomplete calyx and some secondary damage in the apical region. Impressed areas occur at the apex on both counter and cardinal sides. Originally this specimen must have been more than 11.8 mm. in length. Thirty-seven major septa can be counted in the lower part of the calyx (cardinal-counter dimension, 8.7 mm.; alar, 11 mm.). Minor septa are not discernible. The columella and surrounding axial complex are less conspicuous than in the holotype and figured paratype (USNM 124801). This specimen is interpreted to represent an early ephebic stage of *Bighornia parva*, and is of particular interest for comparison with a closely similar growth stage of *B. anticonvexa*.

A third paratype (pl. 70, fig. 1–4) was an incomplete specimen from which four transverse thin sections were made. A partial section near the floor of the calyx (pl. 70, fig. 4) shows the structure and relationships of the columella and associated axial complex at dimensions estimated to be about 9 mm. by 12 mm. A markedly triangular transverse section (pl. 70, fig. 3) measuring 8 mm. by 10.5 mm. exhibits 37 major septa. The width of the marginal stereozone is about the same as it is in the section near the calyx floor, but the interseptal loculi are much reduced. A third section (pl. 70, fig. 2) (dimensions: 7.5 mm. by 10 mm.) shows 33 or 34 major septa unusually dilated and obliterating the interseptal loculi except the cardinal fossula. At a still earlier neanic stage (pl. 70, fig. 1) (dimensions: 5.5 mm. by 8 mm.) there are 30 major septa, the cardinal septum is longer than in later stages, and the cardinal fossula is correspondingly reduced in extent. Still nearer the apex, the cardinal septum extends to the center and the corallum is entirely filled with septal deposits.

Another sectioned paratype (pl. 70, fig. 5–7) has 35 major septa in the latest neanic or earliest ephebic stage (dimensions near base of calyx: 7.5 mm. by 9.5 mm) (pl. 70, fig. 7), and 32 major septa in a late neanic

stage (dimensions: 5.25 mm. by 7.5 mm) (pl. 70, fig. 6).

Types.—Holotype, USNM 127574; figured paratypes, USNM 124801, 127576, 127577; unfigured paratype, USNM 127575.

Discussion.—As mentioned before, most of the species referable to the genus are not described in sufficient detail for comparative purposes. Three of the species—*Bighornia integriseptata* (Parks), *Bighornia? lata* (Teichert), and *Bighornia? oppleta* (Teichert)—have relatively large coralla that range from 35 mm. to 50 mm. in length. Major septa in the ephebic stages of these forms number more than 50—there are as many as 65 in *B.? lata*. Transverse sections through the ephebic regions are essentially circular. These features serve to differentiate the three species from *B. parva*.

Two of the previously described species are of medium size; the ephebic coralla range from about 20 mm. to 35 mm. in length. *Bighornia solearis* (Ladd) is interpreted to have an average of 45 major septa in the early ephebic stage; as described, the holotype has about 50 major septa at the rim of the calyx. *Bighornia patella* (Wilson) is inferred to have a corallum 25 or 30 mm. in length; no information is available on the number of major septa. One of the syntypes of *Bighornia scheii* (Cox) probably belongs to the medium-sized group of species; unfortunately only a longitudinal section of this specimen was figured and the number of septa was not recorded.

In addition to the genotype, species characterized by small coralla (10 mm. to 20 mm. in length in ephebic stages) include *Bighornia anticonvexa* (Okulitch), some of the syntypes of *B. scheii* (Cox), and the specimens Troedsson identified as *Streptelasma* aff. *breve* Ulrich. *S. breve* (Ulrich, 1895, p. 92–93, fig. 7) is a good *Streptelasma* characterized by turbinate to patellate nonangulate coralla that are convex on the cardinal side; the cardinal septum is long. Troedsson's specimens clearly belong to *Bighornia* and are comparable to *B. parva*, n. sp., in size, shape, and number of major septa. *B. anticonvexa* differs from the genotype in having considerably fewer major septa (an average of about 30) in early ephebic stages and fairly long alternating minors that project into the calyx. Specimens of *B. anticonvexa* and *B. parva* resemble each other closely in size and shape, but transverse sections of comparable dimensions invariably show that *B. parva* had about 10 more major septa and that its minors were surpressed and confined to the peripheral stereozone. From Cox's illustrations, it seems likely that some of the snytypes of *B. scheii* are conspecific with *B. anticonvexa*.

Occurrence.—Reddish weathering shaly beds at the top of the Bighorn dolomite; SW¼ sec. 25, T. 52 N., R. 84 W.; south fork of Rock Creek, Bighorn Mountains, Fort McKinney quadrangle, Johnson County, Wyoming; USGS locality catalog Nos. 1362-CO and 68-SD.

Associated fossils.—The fauna collected at this locality in 1904 (USGS locality 68-SD) was identified by Ulrich and listed by Darton (1906, p. 38) in the report on the Bighorn Mountains. Additional collections were made subsequently at the same place (USGS locality catalog Nos. 1362-CD, 1-SD, 50-SD and 1696-SD). All the material has been studied and largely reidentified in recent years. Some of the most characteristic fossils are listed here.

Corals (identified by Helen Duncan)

Bighornia anticonvexa (Okulitch)
Bighornia parva, n. sp.
Bighornia aff. *B. patella* (Wilson)
Favosites (*Palaeofavosites*) cf. *F. prolificus* Billings
Streptelasma aff. *S. latusculum* (Billings)
Streptelasma trilobatum Whiteaves

Bryozoa in USGS 1362-CO (identified by R. S. Boardman and Helen Duncan)

Arthroclema angulare Ulrich
Batostoma manitobense Ulrich
Bythopora? sp.
Dicranopora emacerata (Nicholson)
Dicranopora fragilis (Billings)
Goniotrypa cf. *G. bilateralis* Ulrich
Hallopora sp.
Helopora? sp.
Nematopora? sp.
Pachydictya sp.
Proboscina frondosa (Nicholson)
Rhombotrypa cf. *R. quadrata* (Rominger)
Sceptropora facula Ulrich
Trematopora aff. *T. cumingsi* Troedsson

Brachiopods (identified by Josiah Bridge)

Diceromyonia subrotundata Wang
Diceromyonia tersa (Sardeson)
Dinorthis (*Plaesiomys*) cf. *D. proavita* (Winchell and Schuchert)

Lepidocyclus perlamellosus (Whitfield)
Lepidocyclus rectangularis Wang
Megamyonia sp.
Öpikina? cf. *O. limbrata* Wang
Rhynchotrema iowense Wang
Strophomena? *perconcava* Wang

Ostracodes in USGS 1362-CO (identified by Jean M. Berdan)

Ceratopsis sp.
Drepanella? sp.
Krausella sp.
"*Primitia*" cf. "*P.*" *lativia* Ulrich
Schmidtella sp.
Tetradella sp.

Ulrich and other workers considered this fauna to be indicative of Richmond age. The brachiopods are comparable to species described from the Maquoketa shale of Iowa (Wang, 1949). Most of the corals and bryozoans are identical with forms that occur in the Stony Mountain formation of Manitoba (Whiteaves, 1895, p. 113,115–118; Okulitch, 1943; Baillie, 1952, p. 32–34). In Ulrich's original list, corals now assigned to *Bighornia* were identified as *Lindströmia*. The forms that Ulrich identified as *Streptelasma rusticum* and *S.* cf. *robustum* are now called *Streptelasma* aff. *S. latusculum*.

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ON THE TETRACORAL *LITHOSTROTION HARMODITES* MILNE-EDWARDS AND HAIME

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ABSTRACT—Corals from the Ste. Genevieve limestone (Meramec, Mississippian) of the Ohio River Valley which have long been referred to *Lithostrotion harmodites* Milne-Edwards and Haime are named *Lithostrotion* [*Siphonodendron*] *genevievensis*, n. sp. *L. harmodites* is a Silurian coral from the Great Lakes region and is probably conspecific with *Synaptophyllum multicaule* (Billings). *S. multicaule* may be a junior subjective synonym of *L. harmodites*.

INTRODUCTION

SINCE the turn of the century a vast amount of work has been done on the stratigraphy and paleontology of the Mississippian strata of the midwestern United States. In this interval some conflict of opinion arose from time to time as to the correlation and subdivision of rock units near the Meramec-Chester boundary but the presence of *Lithostrotion harmodites* came to have great significance in the discrimination of the Ste. Genevieve limestone, and is consequently one of the most widely recognized organisms in Mississippian studies.

It is apparent from even a casual study of the original figures and description of *Schoenophyllum aggregatum* Simpson (1900, p. 215, fig. 39,40) that it is the same species as *Lithostrotion harmodites* of authors. It has puzzled the writer for a long time as to why the two names should exist when apparently one would be sufficient. During the summer of 1948 the opportunity came to investigate this matter thoroughly. The ramifications of this study and a restudy of various type collections are presented below.

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Institutions lending specimens for this study are hereinafter abbreviated as follows: USNM—U. S. National Museum, Washinton, D. C.; NYSM—New York State Museum, Albany, N. Y.; and IGS—Illinois State Geological Survey, Urbana, Illinois.

SYSTEMATIC PALEONTOLOGY

LITHOSTROTION [SIPHONODENDRON] GENEVIEVENSIS EASTON, n. sp.

Pl. 71, fig. 5–12

not 1843. *Lithodendron irregulare*. Castelnau, Essai sur le Système Silurien de l'Amérique Septentrionale, Paris, p. 49, pl. 23, fig. 1. [=?*Synaptophyllum multicaule*]. (Silurian, north bank of Lake Huron).

not 1851. *Lithostrotion harmodites* Milne-Edwards and Haime, Arch. Mus. Hist. Nat., Paris, vol. 5, p. 440, pl. 15, fig. 1,1a. [=?*Synaptophyllum multicaule*]. (Carboniferous, North America).

1889. *Lithostrotion harmodites*. Miller, N. Am. Geology and Palaeontology, p. 194. (Carboniferous).

1898. *Lithostrotion harmodites*. Weller, U. S. Geol. Survey, Bull. 153, p. 329. (Carboniferous, North America).

1900. *Schoenophyllum aggregatum* Simpson, New York State Mus. Bull., no. 39, vol. 8, p. 215, fig. 39,40. (No locality).

1905. *Lithostrotion harmodites*. Ulrich and Smith, U. S. Geol. Survey, Prof. Paper 36, p. 42,43,46,47, pl. 5, fig. 14a-f. (Upper Fredonia mbr., Ste. Genevieve ls., Kentucky.)

1917. *Lithostrotion harmodties.* Butts, Description and correlation of the Mississippian formations of western Kentucky, *in* Mississippian Formations of Western Kentucky: Kentucky Geol. Survey, p. 49–51,56,59, pl. 12C; pl. 14, group-figure 15. [Also as *Lithostration* (sic)]. (Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

1917. *Lithostrotion harmodites.* Ulrich, The formations of the Chester. series in western Kentucky and their correlates elsewhere, *in* Mississippian formations of western Kentucky: Kentucky Geol. Survey, p. 32,76,105,108,130,131,133. (Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

1919. *Lithostrotion harmodites.* Miller, Kentucky Dept. Geology and Forestry, ser. 5, bull. 2, p. 108,110,131, pl. 59, group-figure 15. [Also as *Lithosthotion* [sic]]. (Fredonia mbr., Ste. Genevieve ls., Kentucky).

1920. *Lithostrotion harmodites.* Weller, Illinois Geol. Surv., Bull. 41, p. 116. (Fredonia ls. mbr., Ste. Genevieve ls., Kentucky).

1922. *Lithostrotion harmodites.* Butts, Kentucky Geol. Survey, ser. 6, vol. 7, p. 151,152; pl. 69, col. 4, facing p. 140; chart in pocket, cols. 1,23,45. [Also as *L. harmodies* [sic]]. (Top of Ste. Genevieve ls., Tennessee and Kentucky).

1922. *Lithostrotion harmodites.* Cumings, Indiana Dept. Conserv., Pub. 21, p. 508 (not in Indiana, but Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

1923. *Lithostrotion harmodites.* Weller, Kentucky Geol. Survey, ser. 6, vol. 10, p. 29,30. (Upper part of Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

1925. *Lithostrotion harmodites.* Nelson, Tennessee Div. Geology, Bull. 33-A, p. 33. (Fredonia oolite, Tennessee).

1926. *Lithostrotion harmodites.* Butts, Alabama Geol. Survey, Spec. Rept. 14, p. 182. (Not in Alabama, but in Ste. Genevieve ls., Tennessee).

1926. *Lithostrotion harmodites.* Weller, Jour. Geology, vol. 34, no. 4, p. 329. (Higher Ste. Genevieve ls., Kentucky).

?1927. *Lithostrotion harmodites?.* Girty, *in* Mansfield, U. S. Geol. Surv., Prof. Paper 152, p. 70. (Brazer ls., Idaho).

1927. *Lithostration [sic] harmodites.* Weller, Kentucky Geol. Survey., ser. 6, vol. 28, p. 102. (Near top of Ste. Genevieve ls., Kentucky).

1929. *Lithostrotion harmodites.* Butts, Jour. Geol., vol. 37, pp. 36,40. (Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

not 1931. *Lithostrotion ? aff. L. harmodites?.* Girty, in Hewett, U. S. Geol. Surv., Prof. Paper 162, p. 19. (Anchor ls. mbr., Monte Cristo ls., Nevada).

1931. *Lithostrotion harmodites.* Weller, Kentucky Geol. Survey, ser. 6, vol. 36, p. 285,278, pl. 38, fig. 8a-c. (Middle of Ste. Genevieve ls., Kentucky).

1936. *Lithostrotion harmodites.* Hayasaka, Taihoku Imp. Univ., Mem. Faculty Science and Agriculture, vol. 13, no. 5, p. 73. (no locality).

not 1940. *Lithostrotion harmodites.* Hill, A monograph on the Carboniferous rugose corals of Scotland: Paleontograph. Soc. London, p. 168. [=? *Synaptophyllum multicaule*].

1940. *Lithostrotion harmodities.* Weller and Sutton, Am. Assoc. Petroleum Geologists, Bull., vol. 24, no. 5, p. 818. (Upper part, Fredonia ls. mbr., Ste. Genevieve ls., western Kentucky).

?1942. *Lithostrotion harmodites.* Kelley, Jour. Paleont., vol. 16, no. 3, p. 354,360. (Monte Cristo ls., Nevada; Brazer ls., Idaho).

1943. *Lithostrotion harmodites.* McFarlan, Geology of Kentucky, p. 81, (Fredonia oolite mbr., Ste. Genevieve ls., Kentucky).

1943. *Lithostrotionella harmodites.* Schuchert, Stratigraphy of the Eastern and Central United States. Wiley, p. 497,532,592,640. (Fredonia oolite, Illinois, Indiana, Kentucky, Tennessee).

1950. *Schoenophyllum aggregatum.* Bassler, Geol. Soc. Amer., Mem. 44, p. 217. (St. Louis ls., Kentucky).

1950. *Lithostrotion harmodites.* Bassler, Geol. Soc. Amer. Mem. 44, p. 218. (Ste. Genevieve ls., Kentucky).

1952. *Lithostrotion harmodites.* Malott, Stratigraphy of the Ste. Genevieve and Chester Formations of Southern Indiana: Edwards Letter Shop, Ann Arbor , Michigan, p. 8,9,34,58,98. (Bryantsville breccia in Levias ls. mbr., Ste. Genevieve ls., Indiana).

Externals.—Coralla roughly hemispherical, commonly a foot or less in diameter. Corallites loosely connected in approximately parallel bundles (phaceloid), each corallite of which is sometimes separated from its neighbors by a distance about equal to its own diameter, or more commonly so close as almost to touch. Lateral processes occur irregularly.

Corallites cylindrical, slightly sinuous, with parallel septal grooves and faint encircling striae. Diameters usually are about 3 or 4 mm.

A hypotype (USNM 42753) shows positions of the cardinal and right alar septa on the theca so that it can be proved that the long septum attached to the columella is the counter system. Just after budding, this specimen has concentric striae on the theca, but septal grooves soon appear. Minor septa are introduced simultaneously with the appearance of grooves and the septal count remains constant in these long cylindrical corallites, so major septa are not distinguishable from minor septa by studying parallel grooves on the theca.

Transverse sections.—The holotype (upper left specimen on pl. 71, fig. 11) 4.0 by

4.5 mm. in diameter has 16 thin septa most of which extend ¾ of the radius or more and are corrugated within the tabularium. The counter septum is long and axially swollen to form a palicolumella. The probable cardinal septum is the shortest septum, extending only half the radius. Two broad tabular intersections cross the tabularium and two extra tabulae or dissepiments occupy one loculus in the right counter quadrant. Dissepiments in a single row form a prominent inner wall. No minor septa are present.

Two other syntypes agree in details with the one above, except that they both have 14 septa and no extra tabulae in any loculus.

Longitudinal sections. A syntype (left specimen, pl. 71, fig. 12) has 13 dissepiments on the right side and 10 on the left. No dissepiments occur in the upper left portion. At two places 2 rows are present and in one place 3 rows occur. The columella is thick and sinuous. Tabulae are mostly complete and about 11 occur in 1 cm. Tabulae commonly slope away from the axis at 15°. Their axial ends often are bent up and their peripheral edges down, but some have their peripheral edges bent up also so that tabulae sag between the palicolumella and the dissepimentarium. Part of the solid (thecal?) substance in a lateral process adheres to this specimen.

A hypotype (pl. 71, fig. 9) has 8 or 9 tabulae in 5 mm. and 5 or 6 dissepiments in 5 mm. The columella is wrinkled on its lateral surface and has a dark axial line with thick stereome.

Occurrence.—L. genevievensis has long been considered to be particularly characteristic of the Fredonia oolite member of the Ste. Genevieve limestone in the Ohio River Valley, but Malott (1952, p. 8,9) questioned the reference of some, if not all of the references to the Fredonia oolite and cited the species in southern Indiana and in part of Kentucky as definitely from the Bryantsville breccia at the top of the Levias limestone member of the Ste. Genevieve ls. This difference of opinion should be invstigated further.

Types.—The syntypes are New York State Museum no. 3700/1 bearing type number 314, and 3700/2 bearing type number 315. Hypotypes are U. S. National Museum nos. 37463, 42753, and 115213; and Illinois Geological Survey 5P10a–b. The Illinois Survey's specimens are from the top 4 feet of Malott's (1952, p. 98) Levias limestone member of the Ste. Genevieve limestone in the old roadside quarry 1.5 miles NW of Mitchell, Indiana, SE, SW, NE, sec. 34, T. 4 N., R. 1 W., Lawrence County. USNM 37463 is in the Rominger collection and is reportedly from the St. Louis limestone of Kentucky, but this presumably means Ste. Genevieve limestone in current terminology. USNM 42753 is from the Ste. Genevieve limestone at Princeton, Kentucky and is in the Ulrich collection.

Remarks.—The syntypes are represented by thin 5 sections of which 3 transverse sections are on one slide and 2 longitudinal sections are on another. It cannot be proved that all of the specimens came from the same colony, although this is quite possible; at least no matrix connects them on the slides. One of the transverse thin sections (upper left specimen on pl. 71, fig. 11) which was figured by Simpson (1902, fig. 39 on p. 215) is herewith designated the holotype. It is mounted together with 2 other syntypes on a slide as NYSM 3700/1 bearing type number 314. The other specimen figured by Simpson (1902, fig. 40 on p. 215) is also refigured herein (left specimen on pl. 71, fig. 12). The original idealized figure was inverted and shows about twice as much length as does the thin section of the syntype from which it was (at least in part) taken. Simpson's figure 40 can no longer be completed from any section observed in the collections.

In view of the fact that the type material is represented only by thin sections, it is desirable to have additional material for future studies. It is established that U. S. National Museum specimen 37463 is suitable for a hypotype. It is a representative portion of a corallum, is cleanly preserved, and contains transverse and longitudinal polished surfaces. Inasmuch as the writer could match every structure and proportion of NYSM 3700/1 and 3700/2 (bearing type numbers 314 and 315) in USNM 37463, he is convinced that all of the foregoing material is conspecific.

Simpson (1902, p. 215) called the counter septum the cardinal septum, but he then

oriented the transverse section (his fig. 39) with the true counter position toward the top of the page just like he did with corals like *Triplophyllum* and *Hapsiphyllum* in which two instances he had the septal planes correct. It is clear that it is the counter septum which is long and which is attached to the palicolumella. Simpson (1902, p. 215) thought that *L. harmodites* had a simple palicolumella isolated from all of the septa, whereas his material has the true counter septum attached to the palicolumella. He therefore erected *Schoenophyllum aggregatum* for the latter group of corals. It is clear that he was led astray by a figure of a calyx of one of the types of *L. harmodites* in which a free columella was erroneously depicted (Milne-Edwards and Haime, 1851, pl. 15, fig. 1a).

The character of the axial halves of the septa in being corrugated (combining appearances of being zig-sag, sinuous, and differentially thickened) has been considered by Hudson (1943, p. 27) to indicate a condition of old age in *Rotiphyllum*.

The writer questions citations of this species from Cordilleran areas. Material collected by the writer from the Monte Cristo limestone of Nevada, for instance, is closer to *Lithostrotion pauciradiale* (McCoy), 1844, than it is to *L. genevievense*.

Small phaceloid *Lithostrotion* from Europe resemble *L. genevievensis* in habit, but generally have longer minor septa and more complicated columellae. One of these species, *L. junceum* is figured herein (pl. 71, fig. 5,6) for purposes of comparison. It has incipient lamellae in contact with the columellar rod, for instance.

In 1943 Castelnau published a significant work on North America geology, entitled "Eassai sur le Système Silurian de l' Amerique Septentrionale." In it he mentioned and figured, among other fossils, a coral which he identified as *Lithodendron irregulare* Phillips, 1836. The description simply stated:

> This colony is composed of ramose tubes, finely striated lengthwise and possessing transverse swellings. (Writer's translation).

The figure accompanying Castelnau's description (reproduced herein, pl. 71, fig. 1) is unidentifiable and the description is applicable to various genera of corals and bryozoans. The specimen was said to have been collected from the north shore of Lake Huron. Only Silurian strata are yet known to crop out there or in the nearby islands in the lake.

When this identification was made by Castelnau (1843) there was an active controversy as to the status of the Silurian. Not until 1879 was the Ordovician proposed to take the place of what had variously been referred to as Upper Cambrian or Lower Silurian. As a result of the uncertain usage of Siluran, it is perhaps not surprising that most later workers seem to have ignored Castelnau's stratigraphic determination of the locality of *Lithodendron irregulare* as being Silurian. In any case, Castelnau was right about the age, even in terms of modern usage.

In 1851 Milne-Edwards and Haime pointed out that the specimen Castelnau identified as *Lithodendron irregulare* is not properly referable to Phillip's species. They renamed it *Lithostrotion harmodites* and described the new species as follows:

> Colony fasciculated; corallites cylindrical, slightly flexuous, in general separated among themselves by one or one and a half times their diameter, enclosed with a complete epitheca, and presenting rather pronounced bourrelets; these corallites are united among themselves by well-developed connecting tubes like those of syringoporoids; calyces circular; columella small, a little compressed; the 18 principal septa alternating with an equal number of very small septa are slender, almost straight, arriving almost at the center of the tabulae, which are well developed and reasonably horizontal. Diameter of corallites, 5 millimeters. (Writer's translation).

The locality given to accompany this description was "Carbonifère *Amerique septentrionale* (Castelnau)."

Two generalized figures were given, one of a colony and one of a calyx.

Milne-Edwards and Haime renamed Castelnau's species, and presumably had it at hand at the time (1851), but although they commented upon the original figure as being inadequate, they did not refigure it. Instead, they figured a gross view of a colony in their collection and an enlarged view of a calyx, probably or possibly from a different specimen. More than one specimen is in the type collection, because Hill (1940, p. 168) referred to the syntypes she examined.

It seemed to the writer that the colony was not particularly like colonies of what midwestern paleontologists have long considered to be typical of *Lithostrotion harmodites*. For one thing, there are too many connecting processes in the figured colony. Moreover, the stylized calicular view, although resembling calyces of the latter species somewhat, contains much longer minor septa than does *L. harmodites*. Accordingly, the writer selected a fine example of what American paleontologists call *Lithostrotion harmodites* (USNM 37463) and sent it to Paris, France, to be compared with the types of Castelnau's and Milne-Edwards and Haime's species. Dr. Ranson reports that they have Castelnau's type and that:

> Nous avons aussi des échantillons du terrain carbonifère d'Indiana qui correspondent très exactment au type. . . . Nous[1] pensons que votre echantillon n'est mêne pas du même, genre.

Dr. Ranson sent the writer one of those specimens which he mentioned as being from the Carboniferous of Indiana, presumably quoting the label for its locality. This particular specimen is the one from which Milne-Edwards and Haime made their view of the colony of *Lithostrotion harmodites* (1851, pl. 15, fig. 1), and it is herewith designated the holotype. The published figure represents only part of the colony before me (see pl. 71, fig. 4). The lithographer made a somewhat generalized view in 1851, and moreover, the published figure was reversed left for right. This latter inadvertency arose from drawing the original outline correctly on the lithographer's stone, but having it appear on paper as a mirror image of the drawing when the printed impression was made.

The calicular view (Milne-Edwards and Haime, 1851, pl. 15, fig. 1a; reproduced herein pl. 71, fig. 2) was not made from any corallite now preserved in the colony before me. Perhaps it was made from some other specimen in the original collection. Milne-Edwards and Haime mentioned in their description the presence of a small compressed columella. Their calicular view shows this feature, but that view may be a composite drawing. One calyx of the figured colony before me (lower right calyx, pl. 00, fig. 4) has a foreign body partially imbedded in limestone matrix on the floor of a calyx in such a way as to give the appearance of a compressed columella. This misleading feature may have some bearing on their statement that a columella is present. Clearly exposed calyces of their figured colony (pl. 71, fig. 3) definitely do not have columellae.

The figured calyx shows 18 straight major septa extending about $\frac{3}{4}$ of the distance to the columella. The 18 minor septa shown extend uniformly about $\frac{1}{4}$ of the distance to the columella. Neither of these features is typical of *Lithostrotion harmodites* as understood by American paleontologists. In the first place, the long septa are usually somewhat contorted. Moreover, the counter septum almost always is connected with the columella. If minor septa are observed at all, they are very short, hardly being more than septal ridges, which rarely cross the dissepimentarium. Lastly, there is generally some indication of dissepiments in specimens which show traces of minor septa but no dissepiments are depicted in the original figure. In view of these considerations, it is not possible to ally the figure with what is now called *Lithostrotion harmodites*.

Another discrepancy concerns the type locality of the species. *Lithodendron irregulare* as identified by Castelnau was collected from an area of Silurian rocks, yet Milne-Edwards and Haime gave the locality of their material as Carboniferous of North America and seemingly cited Castelnau as authority. From communication with Dr. Ranson, the writer learned that the label on the specimen figured by Milne-Edwards and Haime does give Carboniferous of Indiana as the occurrence. Ordinarily one would not be able to resolve this contradictory locality information, but the large specimen figured by Milne-Edwards and Haime is before me. Interesting to say, it is not the Carboniferous species commonly called *Lithostrotion harmodites*, but is a species of *Synaptophyllum*, very close, if not conspecific with *S. multicaule* (Billings) from the Silurian. It seems conclusive therefore that Milne-Edwards and Haime con-

[1] Dr. Ranson and Dr. Alloiteau.

fused their colony with similar colonies from the Carboniferous of Indiana.

It may be argued that Milne-Edwards and Haime were merely renaming Castelnau's species, and hence, that the name *Lithostrotion harmodites* must be based upon Castelnau's type. Either eventuality does not materially alter the problem of what name to apply to the Carboniferous species, because Drs. Ranson and Alloiteau assure me that Milne-Edwards and Haime's colony corresponds "very exactly" with Castelnau's colony. Milne-Edwards and Haime's specimen seems to belong to a species which is known (Bassler, 1950, p. 67,74) to occur in the area and age of rocks which furnished Castelnau's type, but is unknown in Indiana. It follows that there is likelihood that Milne-Edwards and Haime correctly identified their colony with the type, but erred in the published locality. Therefore, by their intent, their deed, and by common convention Milne-Edwards and Haime applied the name *Lithostrotion harmodites* to a Silurian species. As a result, we have erred for almost a century in referring the common colonial rugose coral from the Ste. Genevieve limestone to this species. It seems in retrospect that this misapprehension was caused by three things: (a) similarity of colonial habit, (b) supposed similarity of calyces, and (c) erroneous locality information.

Having had the holotype of *L. harmodites* at hand, the writer appends the following notes to augment original descriptive information (Milne-Edwards and Haime, 1851, p. 440).

Colony loosely phaceloid with the corallites separated about their own diameter. Lateral processes ovate in cross-section with the long axis horizontal. Epitheca with concentric wrinkles and very faint septal grooves. Calyces rather deep, flat-floor, with major septa extending about ⅔ of the radius. Minor septa very short. Septa carinate. Tabulae complete, flat, about 8 in 5 mm. Dissepiments in one to three ranges, about 12 or 13 dissepiments occur on the theca in 5 mm. and are concave upwards where their trace joins the theca. Corallites 4 to 5 mm. in diameter. Theca thin. No columella is present.

In 1902, Simpson erected a new genus and species, *Schoenophyllum aggregatum* to accommodate a coral which he found labelled *Lithostrotion harmodites* in the James Hall collection. Simpson noted that in his material the columella was connected to a long septum, whereas an original figure of *L. harmodites* by Milne-Edwards and Haime (1851, pl. 15, fig. 1a) showed the columella standing free in the calyx. He therefore erected the new binominal for his material. This coral is certainly the same as those commonly called *L. harmodites* by workers from that time until now. Its characters are presented in detail in the morphologic section above.

Simpson thought that the cardinal septum was the long septum attached to the columella, but a study of septal grooves of USNM 42753 shows that here, as in other cases, it is consistently the counter septum which persists in attachment to the columella.

Simpson did not give any type locality or age for his material, but the labels on the syntypes recite that the specimens came from the St. Louis limestone, Glasgow Junction, Barren County, Kentucky. "St. Louis" at that time (1902) generally included the Ste. Genevieve limestone of present terminology (Wilmarth, 1938, p. 1874).

Schoenophyllum Simpson, 1902, however, is an unnecessary duplication of *Lithostrotion* Fleming, 1828, and must be suppressed as a junior subjective synonym. Thus, one might refer to *Lithostrotion aggregatum* (Simpson), 1902.

Recent advances in taxonomy of *Lithostrotion* and its allies have led to the recognition of several genera-like trends in a colony, which trends are called genomorphs. McLaren and Sutherland (1949, p. 626) have shown in an admirably lucid figure the relationships of septal continuity, columellar form, and growth habit amongst these diverse groups. Accordingly, one finds that corallites in most *Lithostrotion* are crowded into prismatic shapes, but some are loosely grouped into bundles with circular cross-sections. This latter group, which has been called by the generic name *Siphonodendron* McCoy, 1849, is quite patently the group to which *Lithrostrotion aggregatum* belongs. Some students do not think that the

growth habit merits generic distinction, but it still does at least warrant recognition as a recognizable departure, in the opinion of this writer. Therefore, phaceloid (loosely bundled) corals can be called *Lithostrotion* genomorph *Siphonodendron*, and the species under consideration becomes *Lithostrotion* [*Siphonodendron*] *aggregatum* (Simpson), 1902.

Unfortunately, this concatenation of manoeuvers brings this species into homonymy with *Siphonodendron aggregatum* McCoy in Sedgwick and McCoy, 1851. Being now a homonym, the American name has to be suppressed.

The writer therefore proposes the new name, *Lithostrotion* [*Siphonodendron*] *genevievense* for *Schoenophyllum aggregatum* Simpson, 1902, p. 215. The holotype is the specimen designated above under this subheading entitled "remarks," and is figured herein (upper left specimen on pl. 71, fig. 11).

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ON THE TETRACORAL *ROTIPHYLLUM RADICULA* (ROWLEY) FROM THE MISSISSIPPIAN OF MISSOURI

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ABSTRACT—*Rotiphyllum radicula* (Rowley), 1900 is characterized by rootlets, slightly rhopaloid septa and a depressed axial structure. It is the youngest species of *Rotiphyllum* in North America and occupies a stratigraphic position between the Early Mississippian species of Missouri and Mexico and the Middle and Late Visean species of western Europe.

INTRODUCTION

WHEN Rowley (1908, p. 269) described *Zaphrentis radicula* he mentioned the abundant rootlets on the theca but did not describe internal features, therefore the writer borrowed the specimen for additional study. The septal plan, however, could not be described until a sizeable mass of matrix had been removed from the calyx. This preparation was easy by use of acid because the specimen is thoroughly silicified but the obscuring matrix was calcareous. The writer is indebted to Dr. H. W. Scott of the University of Illinois for permission to borrow and prepare the specimen, and to redescribe this species.

SYSTEMATIC PALEONTOLOGY

ORDER TETRACORALLA

FAMILY METRIOPHYLLIDAE

GENUS ROTIPHYLLUM Hudson, 1942

1942. *Rotiphyllum* Hudson, Geol. Mag., vol. 79, no. 5, p. 257.

Remarks.—Synonymy and Hudson's diagnosis have been published by the writer elsewhere (Easton, 1944, p. 32).

ROTIPHYLLUM RADICULA (Rowley), 1900

Pl. 71; fig. 13–16

1900. *Zaphrentis radicula* Rowley, Amer. Geologist, vol. 25, no. 5, p. 269, pl. 5, fig. 7,8. (Lower Burlington limestone, Missouri).

1908. *Zaphrentis radicula.* Rowley, Missouri Bur. Geol. Mines, ser. 2, vol. 8, p. 38 (4th Lower Burlington, Missouri).

Externals.—Coral simple, measuring 18 mm. in length, and consisting of three portions separated by zones of contortion. The apical portion is cylindrical, with a length of 3 mm. and a diameter of 2 mm. The base is a concave expansion, presumably where it was attached to some smooth object. The middle portion expands at about 60° to meet the distal third which flares only at 30°.

The theca is devoid of interseptal ridges and septal grooves, but is covered with minute growth lines. Peculiar, shallow slits which indent the theca here and there are seemingly opposed to the traces of major and minor septa in the calyx. Spines which project away from the theca at various angles are particularly abundant in zones near the rim and at the portion with a 60° flare.

Calyx.—The roughly circular calyx is 13 mm. in diameter and 6 mm. deep. Tips of the major septa are embedded in an axial stereome which occupies a depression 2.5 mm. in diameter and about 1 mm. below the ends of the septa. The 24 major septa are mostly slightly swollen axially and are slightly twisted counterclockwise. The cardinal septum extends as far axially as the other major septa do but is thin and not as high in the calyx. Only an indistinct cardinal fossula is present and this is on the convex side of the corallite. The counter septum is longer than any other major septa and its axial end is bent clockwise. Each of the cardinal quadrants contains 5 major septa and each of the counter quadrants contains 6 major septa. The major septum nearest the cardinal septum in the right cardinal quadrant seems to have been almost aborted, and it leans sharply against the next major septum in that quadrant—otherwise it seems at first glance to be the cardinal septum. Alar pseudofossulae are indistinct, but can be detected by grouping of septa if not by slightly wider loculi.

Secondary septa occur as ridges between most major septa. No dissepiments or tabulae were observed, although the latter may well be present below the calyx. Peculiar swellings between majors at a few places coincide with the thecal slits on the exterior and apparently are not true dissepiments.

This being the only known specimen, no sections were cut.

Comparison.—*R. radicula* is characterized by the prominent rootlets on the theca and by the rhopaloid major septa which are invested in a depressed axial structure. *R. hians* Easton, 1944 differs from this species in lacking rootlets and in having an axial boss in the calyx. *R. calyculus* (Miller), 1891 differs in having a striate theca instead of rootlets, and in having the major septa fused into groups before meeting in a smoothly-floored calyx.

Occurrence.—When Rowley first described this species he cited it as coming from the Lower Burlington limestone at Louisiana, Missouri, but he later (Rowley, 1908, p. 38) narrowed down the stratigraphic unit to be his Coral Zone or "Fourth Lower Burlington Division," which is the 4 foot "Blue Layer" of local usage at the very top of the Lower Burlington. In terms of current stratigraphic nomenclature this bed would be within the *Physetocrinus ventricosus* zone of Laudon (1937, pp. 1161, 1163).

Material.—The holotype and only known specimen is in the University of Illinois, Rowley Collection, RX 14.

Remarks.—*Rotiphyllum radicula* is interesting because it occupies a stratigraphic position intermediate between the previously known species from Missouri and the commonly known species from Europe. *R. calyculus* (Miller), 1891 is from the so-called Chouteau formation of Missouri and is reportedly from beds which Beveridge and Clark (1952, p. 73) would assign to both the Compton and overlying Sedalia formations of the Chouteau group. *R. hians* Easton, 1944 is reportedly from the lower or restricted Chouteau formation, which is the Compton formation of Beveridge and Clark. It appears from the foregoing occurrences that *Rotiphyllum*, as heretofore known in America, occurred at about the Kinderhook-Osage boundary or at the Z_2-C_1 boundary in terms of European nomenclature (Moore, 1948, p. 375). Two species being described by the writer from Sonora, Mexico seem to have been contemporaneous with the Chouteau species from Missouri.

R. radicula, however, occurs in rocks of distinctly Osage age a short distance above any of the foregoing species. This would be up in the C_1 zone of western Europe.

In England *Rotiphyllum* occurs in Middle and Upper Viséan strata from faunal zone S_2 into zone D_3. This range, in terms of American usage, would be from mid-Meramec to mid-Chester (Moore, 1948, p. 375), or entirely above the range of the genus in America.

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MANUSCRIPT RECEIVED JANUARY 2, 1957

EXPLANATION OF PLATE 71

FIG. *1*—*Lithodendron irregulare*. Colony, after Castelnau, 1843, pl. 23, fig. 1, ×½.

2–4—*Lithostrotion harmodites* Milne-Edwards and Haime. *2*, calyx, from Milne-Edwards and Haime, 1951, pl. 15, fig. 1a, probably about natural size; *3*, calyx of a corallite showing long minor septa and absence of columella, holotype, ×2; *4*, corallum (note simulated columella in calyx of lower right corallite), holotype, ×1.

5,6—*Lithostrotion junceum* Fleming, hypotype, USNM 63319, Mountain limestone, N. Wales. *5*, five transverse sections in growth positions in a corallum, ×5; *6*, longitudinal section, ×3.

7–12—*Lithostrotion [Siphonodendron] genevievensis* Easton, n. sp. *7*, transverse section, hypotype, ×5, IGS 5 P 10 b; *8*, transverse section, hypotype, ×5, IGS 5 P 10 a; *9*, longitudinal section hypotype, ×3, USNM 42753; *10*, five transverse sections in growth positions in a corallum, hypotype, ×5, USNM 115213; *11*, three transverse sections not in growth position, syntypes (upper left section is holotype) of *Schoenophyllum aggregatum* Simpson, ×4, NYSM type number 314, photo by NYSM; *12*, two longitudinal sections not in growth position, syntypes of *S. aggregatum* ×4, NYSM type number 315, photo by NYSM.

13–16—*Rotiphyllum radicula* (Rowley), 1900, holotype, University of Illinois RX 14 (Rowley Collection). *13*, basal view, ×1; *14*, side view, ×1; *15*, calyx, ×2; *16*, side view, ×1.

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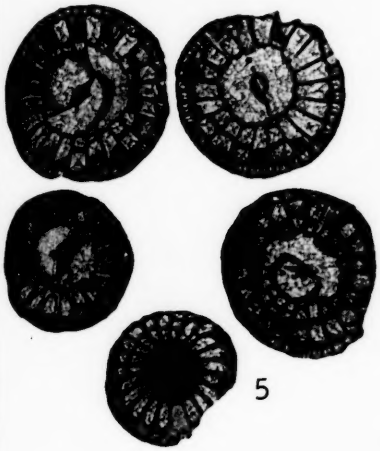
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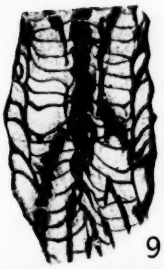
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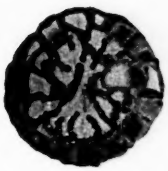
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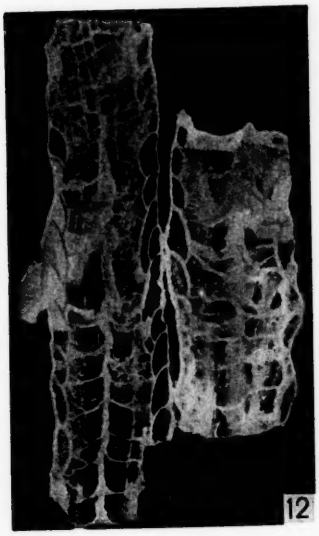
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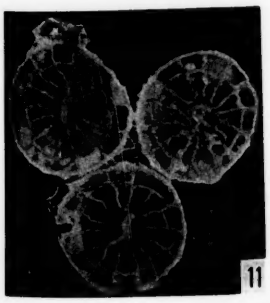
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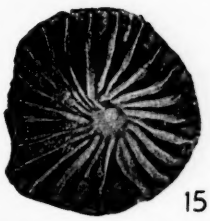
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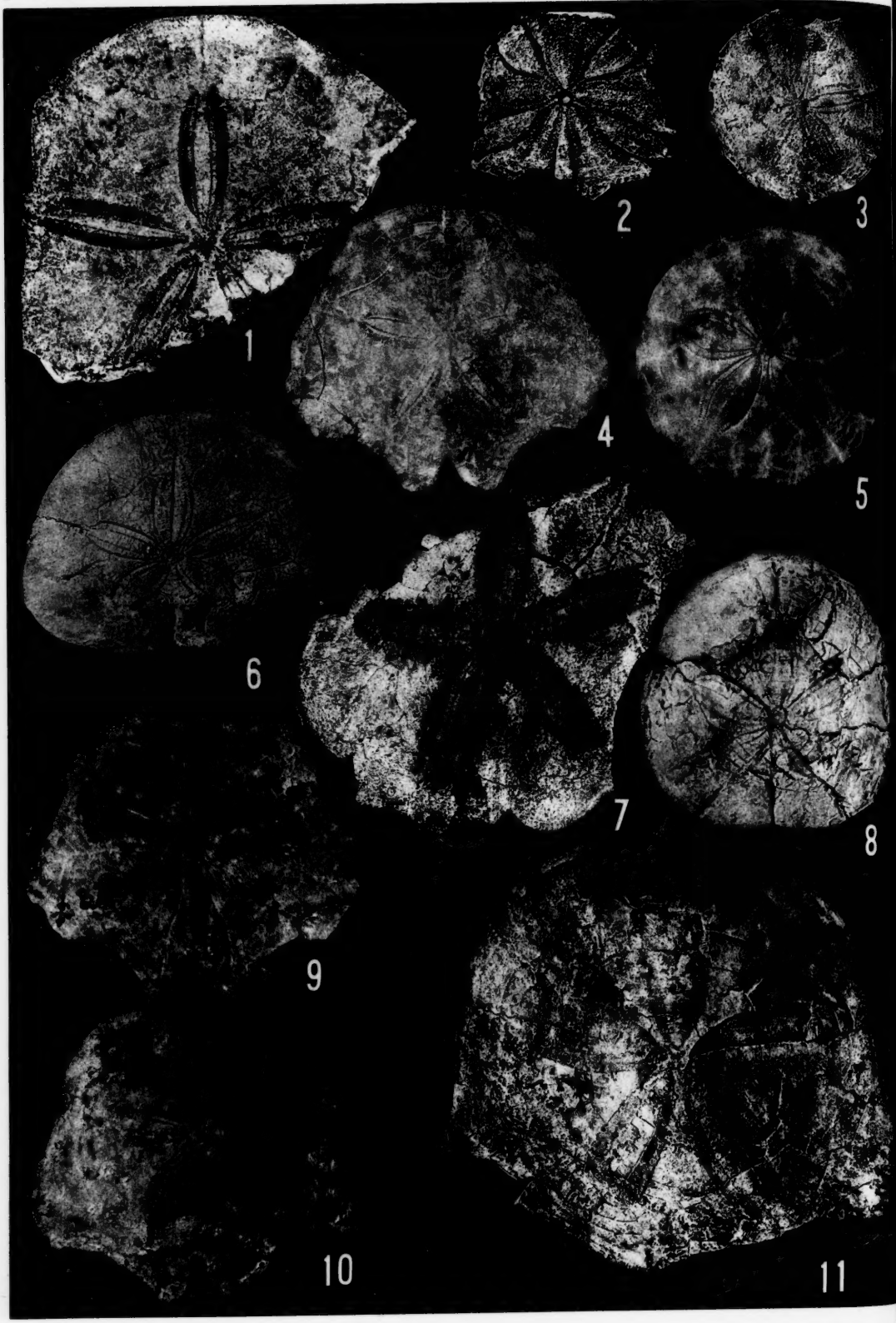
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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 625–631, PL. 72, 2 TEXT-FIG., MAY 1957

NOTES ON ECHINOIDS

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ABSTRACT—During the past few years several new echinoids and significant new occurrences of previously described echinoids in western America, Central America, and Alaska have accumulated and are here presented. The significance of these species and records is discussed in the "remarks" under each.

DESCRIPTIONS

Genus LOVENECHINUS Jackson

Lovenechinus Jackson, 1912, Mem. Boston Soc. Nat. History, v. 7, p. 324–326.

Type species.—Oligoporus missouriensis Jackson, orig. desig.

LOVENECHINUS sp. *cf.* L. SEPTIES Jackson

Hypotypes.—Univ. Calif. Mus. Paleo. nos. 36505, 36506, and 36507.

Occurrence.—Mississippian. Loc. B. 1107, near the top of the Yellow Pine member of Monte Cristo limestone, Mountains Spring Pass, Nevada (see text-fig. 1). Collector R. L. Langenheim, Jr., June, 1954.

Remarks.—Parts of 3 specimens are exposed on a weathered limestone surface. One is flattened, the other two seem to represent the adoral region and apparently are but little crushed. The original diameter of the largest (no. 36505) was probably 75 mm. or better. The smaller specimen had a diameter of perhaps 50–60 mm. On the larger specimen the interambulacra may have had a width of around 25 mm. near the ambitus, while the ambulacra were about 9 mm. wide nearer the peristome. On the smaller specimen (no. 36506) the ambulacra are about 10 mm. wide and the interambulacra about 23 mm. wide at the ambitus. A comparable width is indicated for the ambulacra on the badly crushed specimen. On the smaller specimen the interambulacral plates near the ambitus, with a width of about 3 mm., are approximately 4 mm. thick, on the larger specimen they are about 5 mm. thick. On both the better preserved specimens there are seven columns of interambulacral plates near the ambitus. The ambulacra have four columns of plates, with the occluded plates considerably wider than the demiplates, in all parts of the areas where they can be seen. The occluded plates meet the demiplates laterally with a serrate suture like that of *L. septies*. The external surface of the plates is not visible on any of the specimens.

These specimens most closely resemble

EXPLANATION OF PLATE 72

FIG. *1,7—Abertella kewi* n. sp., (×0.8). 1, paratype, Univ. Calif. Mus. Paleo. no. 36496; 7, paratype, Univ. Calif. Mus. Paleo. no. 36497. Both specimens from near town of Simojovel, Chiapas, Mexico. Middle (?) Miocene. Outline of anal notch in part restored on fig. 7.

2—Vaquerosella sp. indet., (×2). Hypotype, Univ. Calif. Mus. Paleo. no. 36500, loc. A 3852. From near Molalla, Oregon. Lower Miocene. Internal mold (incomplete) showing radial partitions and impression of inner surface of petals.

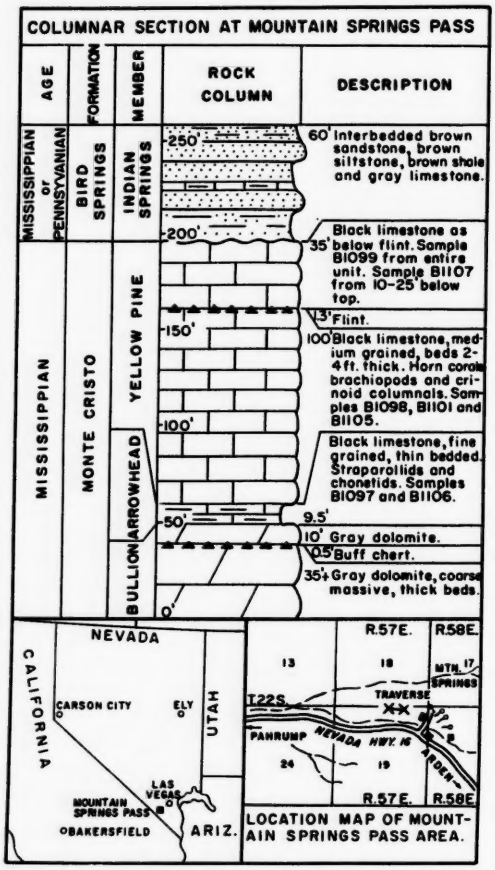
3—Kewia sp. indet., (×1.4). Hypotype, Univ. Oregon, Dept. Geol. no. 372. "Two miles east of Eugene along main track of Southern Pacific [Railway]." Lower Oligocene, Eugene formation.

4,9,10—Abertella palmeri n. sp., (×0.8). 4,9, holotype, Univ. Calif. Mus. Paleo. no. 36503; 10, paratype, Univ. Calif. Mus. Paleo. no. 36504. Both from Univ. Calif. Mus. Paleo. loc. B 2868, Rio Salinas, western Peten Province, Guatemala. Early (?) Miocene.

5—Echinarachnius parma (Lamarck), (×0.8). Hypotype, Calif. Acad. Sci. coll. no. 9531. Point Barrow, Alaska. Recent.

6,8—Echinarachnius alaskense n. sp., (×0.8). 6, holotype, U. S. Nat. Mus. no. 562073; 8, paratype, U. S. Nat. Mus. no. 562074. Both from southeast shore of Cenotaph Island, Lituya Bay, Alaska. Pliocene.

11—Vaquerosella coreyi Durham, (×0.85). Hypotype, Univ. Calif. Mus. Paleo. no. 36502, loc. B 2366, Big Tar Canyon, Kings County, California. Middle Miocene Temblor formation.



TEXT-FIG. *1*.—Index map and columnar section at Mountain Springs Pass, Nevada.

Lovenechinus septies Jackson, but differ from the described specimens by the greater width of the ambulacra. Additional better material might show that they fall within the limits of variation of Jackson's species. *L. septies* was described from the Warsaw Group at Booneville, Missouri. The similarity of these specimens to that species may indicate a similar age for the Yellow Pine member of the Monte Cristo formation at Mountain Springs Pass.

Genus ABERTELLA Durham

Abertella Durham, 1953, Journ. Paleont., v. 27, p. 350–351; 1955, Univ. Calif. Publ. Geol. Sci., v. 31, p. 177–178.
Scutella auctores, in part, *non* Lamarck.

Type species.—*Scutella aberti* Conrad, orig. desig.

ABERTELLA PALMERI, n. sp.
Pl. 72, fig. 4,9,10

Test of moderate size, margins thin; ambital outline roughly pentagonal, with posterior ambulacral marginal indentations and well developed anal notch; petals about two-thirds length of corresponding radius, well developed, moderately closed; pore pairs conjugate, outer pore greatly elongated; about 9 tubercles along ridge between adjacent pore pairs midway on petal Ib; interporiferous zone about as wide as adjacent poriferous zone in trivium, narrower in bivium; anterior petal very slightly shorter than paired petals; four genital pores; apical system slightly raised, hydropores very numerous; periproct small, submarginal, close to base of anal notch; peristome small, slightly anterior; food grooves bifurcating close to peristome, with numerous secondary branches near margin; surface covered with abundant fine tubercles, about 12 in 4 mm. at outer end of petal II.

Dimensions of holotype: length 60.5 mm., width 68.9 mm., height 7.4 mm.

Holotype.—Univ. Calif. Mus. Paleo. no. 36503; paratype, Univ. Calif. Mus. Paleo. no. 36504. Two paratypes in Department of Geology of California Academy of Sciences.

Occurrence.—Guatemala, Univ. Calif. Mus. Paleo. loc. B 2868, Rio Salinas, western Peten Province. "Upper Caribe formation." There are ten more or less complete specimens in this lot with no locality data other than the above. The matrix adhering to some of the specimens is a sandy white chalk.

This species compares most closely to *Scutella floridana* Cooke (1942, p. 19, pl. 4, fig. 9–10) which should also be referred to this genus. It differs from that species in the much more marked posterior ambulacral indentations of the margin and by the apical system being less clearly demarcated. Although Cooke's figures are not completely satisfactory, there is a suggestion that the petals in his species are proportionally longer. *Scutella cazonesensis* Kew (1917, p. 132, pl. 19, fig. 1) is a Mexican species of this genus with less well developed posterior marginal and anal indentations as well as wider interporiferous areas.

Scutella habanensis Sanchez Roig (1949, p. 113–114, pl. 33, fig. 2) and *Echinarachnius sebastiani* Jackson (1922, p. 48–49, pl. 7, fig. 5–6, text-fig. 4) are two seemingly related species that probably are referable to this genus. Both have the posterior indentations less well developed than any of the above species.

Because of its similarity to *S. floridana* Cooke, the present species might be of early Miocene age.

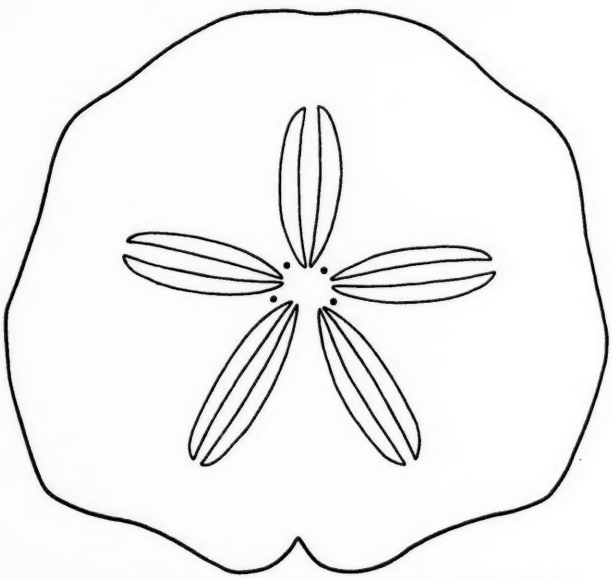
ABERTELLA KEWI, n. sp.
Pl. 72, fig. 1,7; text-fig. 2

Test of fairly large size; margins thin; ambital outline rounded pentagonal, with posterior ambulacral marginal indentations and anal notch; anal notch broad and only moderately deep; petals about two-thirds length of corresponding radius, well developed, rather slender, slightly open; anterior petal slightly wider than paired petals; pore pairs conjugate, outer pore moderately elongated; interporiferous zone of anterior petal about as wide as adjacent poriferous zone, in paired petals narrower than adjacent poriferous zone; anterior petal slightly shorter than posterior paired petals; four genital pores; apical system slightly raised, hydropores small, numerous; periproct not exposed on available specimens; peristome small; food grooves bifurcating close to peristome; surface (poorly preserved) covered with abundant fine tubercles (apparently between 15 and 20 per 4 mm. at outer end of petals).

Dimensions.—No individual with complete margins available; holotype, length 88 mm., width 92 mm. (estimated); a large paratype, no. 36498, length +110 mm. (estimated), width 116 mm. (estimated).

Holotype.—Univ. Calif. Mus. Paleo. no. 36495; paratypes, Univ. Calif. Mus. Paleo. nos. 36496, 36497, 36498, and 36499.

All specimens have the thin margin broken to a considerable degree. The holotype is the most complete, but its preservation is such that it cannot be adequately photographed. Based primarily upon the holotype and paratype 36497 (for the posterior area) the outline of the species has been reconstructed (Fig. 2). The ambital outline is similar to that of *"Scutella" cazonesensis* Kew (1917, pl. 19, fig. 1), but both the anal notch and posterior ambulacral indentations are slightly deeper. In



TEXT-FIG. 2.—Ambital outline (reconstructed) and petals of *Abertella kewi* n. sp. (± ×0.8). Based mostly on holotype, Univ. Calif. Mus. Paleontology no. 36495, but posterior margin partly on paratype, Univ. Calif. Mus. Paleontology no. 36497, and other specimens.

addition the narrow interporiferous areas distinguish it from Kew's species which has interporiferous areas wider than the adjacent poriferous areas.

Abertella kewi differs from *A. palmeri* by its broader anal notch, shallower posterior ambulacral grooves and narrower interporiferous areas.

Occurrence.—Miocene (Middle?), from three localities in the vicinity of Simojovel, Chiapas, Mexico. One locality on the southeast edge of the town; one locality about 0.5 km. on road westward from southwest edge of town; a third locality about 3 kms. S70°W from town. All localities appear to represent about the same stratigraphic horizon. At the most distant locality the associated fauna includes a large *Xancus*, *Turritella*, *Anomalocardia*, *Ostrea*, and a large, externally smooth "*Pecten*."

Genus ECHINARACHNIUS Gray, 1825

Echinarachnius Gray, 1825, Ann. Philos., n. s., v. 10, p. 428; Durham, 1955, Univ. Calif. Publ. Geol. Sci., v. 31, p. 163–164.

Type species.—*Scutella parma* Lamarck.

ECHINARACHNIUS ALASKENSE, n. sp.

Pl. 72, fig. 6,8

Echinarachnius gibbesii Rémond, Dall *in* Mertie, 1931, U. S. Geol. Survey Bull. 836, p. 130. *Non Dendraster gibbsii* (Rémond).

Test of medium size, flattened, outline varying from elongate cordate to broadly cordate, margin thin; apical system excentric, situated about two-fifths length from posterior margin; four genital pores; petals well formed, slightly open, anterior petal broadest; anterior petal about as long as anterior paired petals, posterior paired petals three-fourths to five-sixths length of anterior paired petals; length of petals about two-thirds length of corresponding radius; pore-pairs conjugate, outer pore greatly elongated, peristome opposite apical system; ambulacral food grooves simple, extending nearly to margin, apparently with small pair of lateral branches about one-third distance from margin; periproct small, marginal, in posterior indentation of margin; basicoronal plates moderately developed, interambulacral plates larger than ambulacral; posterior interambulacrum separated from basicoronal plate by adjacent first pair of post-basicoronal ambulacral plates; in two specimens examined, anterior interambulacra in contact with basicoronal plates; posterior paired interambulacra slightly separated from basicoronal plates; surface uniformly covered with abundant closely spaced small tubercles, about 25 to 10 mm. near peristome, about 35 in same interval on aboral surface near margin; internal supports well developed in marginal areas; auricles small, fused, on basicoronal interambulacral plates.

Dimensions.—holotype U. S. Nat. Mus. no. 562073, length 48.3 mm., width 61.5 mm., height (estimated) 6.4 mm.; paratype U. S. Nat. Mus. no. 562074, length 55.0 mm., width 53.9 mm., original height (estimated) 8 mm.

Holotype.—U. S. Nat. Mus. no. 562073; paratypes U. S. Nat. Mus. Nos. 562074, 562075, 562076 and 562077. Two topotypes (nos. 36508, 36509) are in the Museum of Paleontology of the University of California (Berkeley). Another pair of topotypes were likewise deposited in the collections of the California Academy of Sciences.

Occurrence.—U.S.G.S., loc. D 170 (T). Along southeast shore of Cenotaph Island, Lituya Bay, Alaska, 1,950 feet S29°W of easternmost cape of island. From a 24 foot sandstone, with abundant echinoids, near the base of a sandstone-siltstone unit resting on volcanics. Pliocene.

This species superficially closely resembles some variants of *Dendraster gibbsii* (Rémond), however the ambulacral food grooves with a stright central trunk show its relationship to *Echinarachnius parma* rather than to the genus *Dendraster*. The open petals, moderately large basiocoronal plates, arrangement of plates on oral surface, and marginal periproct substantiate its reference to the genus *Echinarachnius*. No other species of this genus has developed such a markedly excentric apical system.

The excentricity of the apical system would seem to indicate, that like *Dendraster excentricus*, this species usually lived in a semi-upright position, with the anterior portion of the test imbedded in the substrate, and the posterior portions projecting up above the seafloor.

This species cannot be closely compared morphologically with any of the fossil Japanese species described by Nisiyama

(1940), Hayasaka and Shibata (1952), or Nisiyama and Hashimoto (1950) nor with any of the living species. The marked eccentricity and cordate outline are characteristic.

The occurrence of these echinoids in the late Tertiary of Lituya Bay, Alaska was first reported in the paper by Mertie (1931). During 1952 D. J. Miller of the U. S. Geological Survey collected additional material (U.S.G.S. loc. D 170 [T]) which was turned over to the present author for description. The specimen here designated as the holotype is one identified by Dall as *Echinarachnius gibbesii* and thus listed in Mertie's paper as from locality 17932 although its correct locality number is 7932. The material listed in that paper as *Echinarachnius* sp. (Mertie, 1931, p. 129) from U.S.G.S. locality 643 has been found and represents the same species. According to Miller (personal communication, Dec. 23, 1955) Dall's material from locality 7932 is undoubtedly from the same place as his locality D 170 (T).

Miller describes the Tertiary section in the Lituya Bay area as follows:

> (1) Basal marine unit consisting predominantly of siltstone, 1,200 to possibly as much as 4,400 feet thick and resting unconformably on pre-Tertiary metamorphic rocks; (2) volcanic rocks interbedded with and grading laterally into conglomerate, sandstone and siltstone, nonmarine and marine, 0 to 1,200 feet; (3) interbedded marine sandstone and siltstone, 600 to possibly as much as 2,500 feet, in gradational contact with overlying (4) marine unit consisting of "conglomeratic" mudstone (marine tillite) interbedded with sandstone and siltstone, at least 9,000 feet thick. The echinoids were collected near the base of the sandstone-siltstone unit, about 180 feet stratigraphically above an apparently conformable contact with the volcanic unit.

Miller further quotes L. G. Hertlein on the age of the sequence, as follows: "The faunal content of the 'mudstone' and 'sandstone-siltstone' units is considered to be one faunal unit whose closest correlative is the fauna of the Empire beds at Coos Bay, Oregon, of Pliocene age. The present fauna is believed to have lived in comparatively shallow water not exceeding 100 fathoms and mostly less than 50 fathoms, at times perhaps slightly brackish, and with climatic conditions perhaps somewhat similar to those now prevailing between Puget Sound and northern California."

The courtesy of Miller and Hertlein in calling attention to this unusual *Echinarachnius* is greatly appreciated. Thanks also due to George O. Gates, Chief of the Alaskan Geology Branch, and to the Director of the U. S. Geological Survey for permission to publish on this echinoid and its occurrence.

ECHINARACHNIUS PARMA (Lamarck)
Pl. 72, fig. 5.

Scutella parma Lamarck, 1816, Hist. nat. anim. s. vert., v. 3, p. 11.

Echinarachnius parma (Lamarck), Mortensen, 1948, Mon. Echin., v. 4, pt. 2, p. 367–372, pl. 71, fig. 16,23–26.

Hypotype.—Calif. Acad. Sci. no. 9531; Univ. Calif. Mus. Paleo. nos. 37551 and 37552.

Occurrence.—Recent, Point Barrow, Alaska, along the Pacific Coast from Puget Sound northwards, and along the Atlantic Coast from Massachusetts northward.

Remarks.—Mortensen (1948, p. 373), Durham (1955, p. 164), and others have noted the apparent discontinuous distribution of this northern sand dollar which occurs on both the northeastern and northwestern coasts of North America, but seemingly not in the Arctic. Because of this, it has been postulated that it migrated from the northwest coast to the northeast coast during some warm interglacial epoch of the Pleistocene.

During 1954, G. D. Hanna of the California Academy of Sciences dredged living specimens typical of this species off Point Barrow, Alaska. Since the Boothia Peninsula of northern Canada is the only part of the North American mainland that extends farther north than Point Barrow (and only by a few miles), it thus seems probable that the species has a continuous instead of discontinuous distribution in the American Arctic. On the basis of this occurrence it seems probable that species should also be found off the Arctic coast of Siberia, and the problem then becomes not "when did it migrate from the northwest coast to the northeast coast," but "why has it not reached the northern European seas via the Siberian Arctic coast?" At the moment this question must remain unanswered

because of a lack of information from that area.

Genus KEWIA Nisiyama, 1935

Kewia Nisiyama, 1935, Saito Ho-on Kai Mus. Research Bull. 5, p. 136; Durham, 1955, Univ. Calif. Publ. Geol. Sci., v. 31, p. 164–165.

Type species.—Scutella blancoensis Kew.

KEWIA sp. indet.
Pl. 72, fig. 3

Hypotypes.—Univ. Oregon, Dept. Geology and Geography.

Occurrence.—Eugene formation, lower Oligocene. From near Eugene, Oregon, 1½ miles along Lorane highway from 29th and Willamette Streets, collected by Gerald Wood, except for No. 372 said to be from "Two miles east of Eugene along main track of the Southern Pacific [Railway]," collected by Thomas Condon many years ago (probably near Glenwood or Springfield Junction).

Remarks.—Condon's specimen is from near the top of the Eugene formation, Wood's specimens are from lower in the formation according to information supplied by Ewart M. Baldwin. Condon's specimen retains the apical surface in poor condition but Wood's do not. They all seem to be clearly referable to the genus *Kewia* (for a discussion of this genus see Durham, 1955, pp. 164–166). The periproct is supramarginal and close to the ambitus. The paired petals are not well preserved on Condon's specimen but seem to be slightly closed while the anterior petal appears to be open. On Wood's best specimen the posterior ambulacra are indented in a manner similar to that of *Kewia blancoensis* (Kew), the type species. In this same specimen the internal partition walls can be seen to extend from the ambitus almost to the oculogenital ring on the apical surface, but only about two-thirds this distance on the oral surface. There does not appear to be any supplementary pillars in the ambulacral areas. None of the present specimens is well enough preserved to determine its relationships with *Kewia newcombei* (Kew), *K. blancoensis* (Kew), *K. fairbanksi* (Arnold), or other species of this genus. Condon's specimen has a length of about 22.5 mm. and a width of almost 24 mm. The largest of Wood's specimens is slightly smaller.

This is the first scutellinid echinoid to be recorded from beds commonly referred to the lower Oligocene on the Pacific Coast although the author once saw an indeterminate cross-section of a much larger species in the Quimper sandstone (Durham, 1944, p. 106) near Port Townsend, Washington. Careful search should reveal several species in this part of the section.

Genus VAQUEROSELLA Durham, 1955

Vaquerosella Durham, 1955, Univ. Calif. Publ. Geol. Sci., v. 31, p. 166–167.

Type species.—Scutella andersoni Twitchell.

VAQUEROSELLA sp. indet.
Pl. 72, fig. 2

Hypotype.—Univ. Calif. Mus. Paleo. no. 36500, loc. A 3852.

Occurrence.—Lower Miocene (Durham, et al., 1942), Molalla Quadrangle, Oregon. From tuffaceous marine sediments intruded by basalt in small quarry along Butte Creek about one to one and a half miles east of Scotts Mills, Oregon (about 30 miles south of Portland). Collected by Ewart M. Baldwin in 1951.

Remarks.—This small specimen (length about 16 mm.) is preserved as an internal mold and part (oral surface only) as an external mold in badly leached, highly fossiliferous fine-grained tuffaceous sediments. Although it is much smaller, the angularity of ambital outline of the specimen is strongly suggestive of *Vaquerosella coreyi* Durham (*Scutella norrisi* Kew, 1920, pl. 10, fig. 1a, *non* 1b; and Loel and Corey, 1932, pl. 6, fig. 2; *non Scutella norrisi* Pack). *V. coreyi* is an abundant and widely distributed species (Loel and Corey, 1932, p. 178) in the upper Vaqueros and Temblor formation of California. The suggested similarity of the Oregon specimen to the California species lends some support to the lower Miocene age suggested by Durham, et al. (1942) for the Oregon locality.

VAQUEROSELLA COREYI Durham
Pl. 72, fig. 11

Scutella norrisi Pack, Kew, 1920, Univ. Calif. Publ. Bull. Dept. Geol., v. 12, p. 75–76

(*partim*), pl. 10, fig. 1a (*non* 1b); Loel and Corey, 1932, Univ. Calif. Publ. Bull. Dept. Geol. Sci., p. 178 (*partim*), pl. 6, fig. 2. *Non* Pack, 1909.

Vaquerosella coreyi Durham, 1955, Univ. Calif. Publ. Geol. Sci., vol. 31, p. 167.

Hypotypes.—Univ. Calif. Mus. Paleo. nos. 36501 and 36502, loc. B 2366.

Occurrence.—Temblor formation, Middle Miocene, Reef Ridge California. From the upper member of *Aequipecten* zone (Stewart, 1946, p. 100).

Remarks.—This species was not observed in the beds exposed in the bottom of Big Tar Canyon, but fragments became increasingly common southward along the strike towards the top of the ridge. Local concentrations of abundant fragments were found in several places and a few fairly complete specimens were collected. Hypotype no. 36501 has a length of 102 mm. and a width of 107 mm. The best preserved specimens are extremely similar to the type specimen of *Vaquerosella coreyi* except for a slightly greater width of the poriferous zone in the petals. This feature is highly variable in different individuals from a population of living *Dendraster excentricus* and is thus believed to be without specific significance. Furthermore one poorly preserved specimen seems to have the narrow poriferous zones of the type specimen. On hypotype no. 36502 the anterior and two antero-lateral petals are wide open and of similar width, but the two posterior petals although wide open seem to be slightly narrower.

This seems to be the first record of this species within the San Joaquin valley area. Loel and Corey (1932, p. 178) have reported from the La Panza mountains and have indicated that it ranges from uppermost Vaqueros through the "Transition zone," and into the Temblor.

The relatively thin bed in which *V. coreyi* occurs in Big Tar Canyon also contains abundant *Vaquerosella* [*Scutella*] *merriami;* the common "button" of the Temblor formation. On the basis of abundance, it is tempting to correlate this particular bed with the "button bed" proper of other localities along the west side of the valley. However *V. merriami* has a stratigraphic range both above and below this bed. A variety of mollusca are also present, including *Turritella ocoyana* Conrad and *Aequipecten andersoni* (Arnold).

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 632–640, PL. 73–74, 2 TEXT-FIG., MAY 1957

MACLURITES AND *GIRVANELLA* IN THE GORDON RIVER LIMESTONE (ORDOVICIAN) OF TASMANIA

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ABSTRACT—*Maclurites florentinensis*, n. sp., and *Maclurites* spp. are associated with *Girvanella problematica*, *G. tasmaniaensis*, n. sp., and *G. grandis*, n. sp., in several places in Tasmania in a bed, probably Chazyan, within the Gordon River Limestone (Ordovician).

INTRODUCTION

Maclurites and *Girvanella* have not previously been described from Tasmania, but *Maclurites* was noted some years ago by Dr. I. A. Browne, University of Sydney, in a collection sent to her from the Geological Survey of Tasmania, and remarked upon in her letter to the Director of Mines. Early in 1950 Professor S. W. Carey, University of Tasmania, and I. B. Jennings collected a suite of specimens, including *Maclurites*, from the Gordon River Limestone near Benjamin, a small settlement about 20 miles from Maydena in the central part of Tasmania.

The authors wish to acknowledge the ready assistance of the Australian Newsprint Mills and especially that of Mr. J. Wylie of that organization, of the Goliath Cement Company, and particularly of Mr. R. Best, and of the Eugenana Lime Quarries. Professor Carey assisted with collections and helpful criticism, and Professor G. W. Bain of Amherst College, Massachusetts, kindly made available facilities in his department. Dr. E. Yochelson, U. S. Geological Survey, and Dr. H. B. Whittington, Museum of Comparative Zoology, Harvard, made specimens of *Maclurites* available for comparison.

STRATIGRAPHY

The Ordovician stratigraphy of Tasmania can be summarized as follows:

Junee Group
- Gordon River limestone
- Caroline Creek sandstone and shale
- Owen conglomerate
- Jukes breccia

It will be sufficient for the purposes of this discussion to consider the age limits of the Gordon River Limestone only. In the Florentine Valley area it is underlain by calcareous shales with *Tritoechia* spp. and *Syntrophopsis* sp. (Brown, 1947), trilobites such as *Asaphopsis*, *Tasmanaspis*, etc. (Kobayashi, 1940), and graptolites such as *Dictyonema* and *Didymograptus* spp., all of which indicate an horizon about the *Didymograptus nitidus* zone or in the Upper Canadian. Just west of the Florentine Valley, the base of the limestone contains *Manchuroceras*, *Suecoceras*, *Piloceras* and *Allocotoceras* (Teichert, 1947, and Teichert & Glenister, 1953), which also indicate an Upper Canadianage. The limestone with *Maclurites* and *Girvanella* occurs some hundreds of feet above the base in this area, in which the Gordon River limestone is about 6,000 feet thick. The top of the Gordon River limestone is not so well dated, but in this area contains *Eofletcheria*. Elsewhere, the limestone contains cephalopods such as *Beloitoceras* and *Trocholitoceras* (Teichert & Glenister, 1953), and corals such as *Protaraea* and *Acidolites* etc. (Hill, 1955), which indicate that it extends at least into the Richmondian and perhaps into the Lower Silurian.

OCCURRENCES

Localities mentioned below are shown in text-fig. 1.

Florentine Valley area.—The best exposure of limestone with the two genera in association is near Cashions Creek on the main logging road along the valley, where about 300 feet of limestone contain abundant specimens of both. *Girvanella* forms up to 40% of the rock in places, and on one piece of limestone 60 colonies more than $\frac{1}{8}$th. inch in diameter were counted in an area of 9 square inches. The specimens of *Maclurites* usually occur flat side down-

wards, and in several cases were seen to be encrusted by a stromatoporoid. Other fossils are rare but include strophomenid brachiopods and orthoconic cephalopods. The limestone with *Maclurites* overlies a white, stylolitic, somewhat impure limestone with asaphids and brachiopods. It is overlain by a fine-grained lithoidal limestone. The *Maclurites* limestone is markedly dolomitic and numerous rhombs of dolomite can be seen in section. It contains rare grains of pyrite and is stylolitic.

On the Adamsfield Track, one-half mile east-north-east by east of the bridge over the Florentine River, a small outcrop of limestone contains large specimens of *Maclurites* and some *Girvanella*.

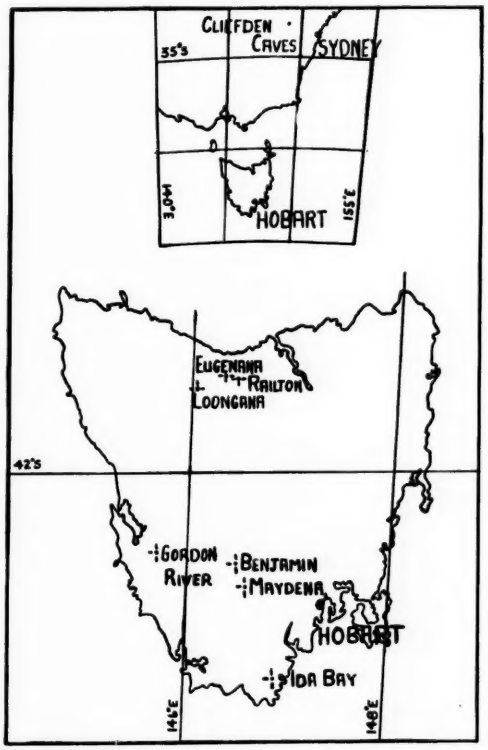
Just east of Benjamin beside the old Dawson Road there are several hills showing outcrops of dolomitic limestone with *Maclurites* and *Girvanella*, showing the same orientation of the gasteropods as at Cashions Creek. Associated with the two genera here are a *Receptaculites*, brachiopods, a bellerophontid, a tall-spired gasteropod (pl. 74, fig. 7), a genus resembling *Maclurites* except for the nucleoconch which is not shown on the flat surface, and an actinoceroid. On the flanks of the Misery Range, several hundreds of feet stratigraphically below the *Maclurites—Girvanella* zone, is an impure limestone with *Tritoechia*. The total thickness of the limestone here is over 5,000 feet.

On the north side of Wherrets Lookout, cutting Karmberg's Track, are outcrops of limestone with *Maclurites* and *Girvanella* overlying a limestone with gasteropods and brachiopods, and overlain by a dolomitic trilobitic limestone.

The *Maclurites—Girvanella* association occurs again on the hill-slope immediately above the entrance to the Junee Caves on the Junee River about 2 miles from Maydena, and here is associated with *Orthonybyoceras tasmaniense* (Teichert and Glenister, 1953).

About a mile south of Maydena in a doline leading to the entrance to Pillingers Creek Caves *Maclurites* and *Girvanella* again occur in association and with them are other gasteropods and some cephalopods.

Ida Bay.—The association occurs also in the limestone at Ida Bay where a bed of



TEXT-FIG. *1*—Map of Tasmania (with inset of south-eastern Australia) showing occurrence of *Maclurites* and *Girvanella* in the Ordovician.

limestone less than 10 feet thick contains both genera. This bed is several hundreds of feet above the base of the formation, which locally contains a *Tetradium* with the growth form of *T. syringoporoides*. Only sections of *Maclurites* were obtainable. Immediately below the *Maclurites-Girvanella* bed is one with *Tetradium* and *Catenipora* and about 100 feet above it is a richly coralline zone which is probably Richmondian (Hill, 1955). It is possible that this occurrence of *Maclurites* and *Girvanella* is not contemporaneous with those in the Florentine Valley but represents a later recurrence of similar ecological conditions.

Gordon River.—Cross sections of *Maclurites* occur in cliffs on the south bank of the Gordon River 3 miles below the mouth of the Franklin River. In the brief time available to examine this limestone *Girvanella* was not seen.

Loongana.—*Girvanella* occurs profusely

in a zone 30 feet thick in medium grey limestone exposed in the cliffs on the south bank of the Leven River about half a mile upstream from Hell's Gates, Loongana. It is associated with a stromatoporoid but despite close search by three people no *Maclurites* was seen.

Eugenana.—*Maclurites* and *Girvalnela* are found associated with a stromatoporoid in a stylolitic, dolomitic limestone at the southern end of the limestone quarry. The zone, here 30 feet thick, overlies unfossiliferous limestone.

Railton.—In the main quarry of the Goliath Cement Works at Railton, a bed of limestone 20 feet thick contains numerous opercula of *Maclurites* and some shells. The limestone is sheared, stylolitic and pyritic. *Zittelella* and bellerophontids occur in the same quarry but no definite *Girvanella* was seen. The limestone in the quarry overlies with some gap the cephalopod beds at Blenkhorns Quarry with *Nybyoceras* spp. (Teichert & Glenister, 1953), which in turn is about 300 feet above the shales of the Caroline Creek sandstone and shale which here contain *Tritoechia.*

As shown later, *Maclurites florentinensis* appears to be most closely related to *M. Magnus,* so that its age is probably Chazyan. Such an age is not inconsistent with the stratigraphic evidence in the Florentine Valley—Maydena area and at Railton, but more detailed work is needed to establish this age.

SYSTEMATIC PALAEONTOLOGY

Algae

Chlorophyta

Genus GIRVANELLA Nicholson & Etheridge, 1880.

The plants consist of tubular filaments which form loose irregular masses or more commonly small compact rounded nodular or bean-shaped bodies. Normally, the tubes have thick well defined walls, and are circular in cross section. Branching is rare in some species, fairly common in others. The sporangia are unknown. Species have been separated on the basis of the tube diameter. The thickness of the wall also appears to be a rather constant specific characteristic. Possibly the angle of branching is also.

The genus has a known geologic range from Lower Cambrian to Late Jurassic.

Our study was based on 25 slides (petrographic thin sections) of limestones rich in *Girvanella.* Several hundred tubes were measured. It is interesting to note that all fell into three groups without any intermediate specimens. Hence, they are considered to represent three species. These are described below.

Localities: Florentine Valley, Junee Caves Pillingers Creek Caves, Ida Bay, Loongana and Eugenana.

GIRVANELLA PROBLEMATICA Nicholson & Etheridge

Pl. 73, fig. 1,4

Girvanella problematica Nicholson & Etheridge, 1880, p. 23, pl. 9, fig. 24.
Girvanella problematica N. & E., Høeg, O. A., 1933, p. 64–65, pl. 1, fig. 4–6.

Description.—Tube diameter 14–17 μ, commonly 16–17 μ, wall thickness 3–4 μ, commonly 4 u. Branching ocurs, but not frequently, at an angle of about 30°. The tubes occur abundantly, often closely packed to form coatings, and small nodular masses. Tubes not parallel, seldom straight for more than short distances. They twist and turn.

Remarks.—In the tube diameter, growth habit, and appearance this form resembles Nicholson & Etheridge's type, and specimens attributed to the same species found at a number of widely scattered localities in several continents. Unfortunately, none of the previous writers have given wall thicknesses.

Chapman (1907, p. 76) describes a form of similar tube dimensions from the Silurian of Victoria which he named *G. conferta.* However, he specifies that it differs from *G. problematica* "in having the tubes in bundles lying side by side, and in being segmented by transverse or oblique partition walls, at which place the tube is generally constricted." Neither of these features were observed in the specimens from Tasmania being discussed.

Occurrence and types.—Figured specimen U.T.G.D. 25945a: Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. U.T.G.D. 21221 (a & b): Gordon River Limestone, Ordovician; on hill slope above mouth of Junee Caves, Junee River, about 2 miles north of Maydena, Tasmania.

U.T.G.D. 25039a, 25043b, 25046b, 25081b, 25084b, 25086, 25088: all from Cashions Creek, Florentine Valley, Tasmania.

GIRVANELLA TASMANIAENSIS Banks & Johnson, n. sp.
Pl. 73, fig. 3.

Description.—Tube diameter 21–23 μ, wall thickness 4–5 μ, commonly 5 μ, Tubes twisted, loosely packed in more or less parallel bundles. Branching moderately abundant, commonly at an angle of 45° to 60°. They form small pellets, or irregular masses or coatings. Some occur in same slide with *G. problematica.*

Remarks.—Høeg (1933, p. 64–65) described a *Girvanella* from the Ordovician of Norway as *G. problematica* forms *moniliformis* which closely resembles *G. tasmaniaensis* in tube diameter and growth habit. However, his species has a somewhat greater range of tube size (20–26 [30] μ), and branches frequently at a considerably wider angle (commonly about 90°).

Occurrence and types. Holotype, U.T.G.D. 25041b: Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. Syntypes, U.T.G.D. 21221b: Gordon River Limestone, Ordovician; hill slope above entrance to Junee Caves, Junee River about 2 miles north of Maydena, Tasmania. U.T.G.D. 25039b, 25042b, 25046a; Cashions Creek locality.

GIRVANELLA GRANDIS Banks & Johnson, n. sp.
Pl. 73, fig. 2,4.

Description.—Tube diameter 31–33 μ, commonly 32 μ. Wall thickness 5–7 μ, normally 6 μ. Tubes twist, loosely packed, in nearly parallel groups of 2 to 4. Branching rare or absent. A few observed cases of apparent branching suggest bifurcation at an angle of about 30°.

Remarks.—This species has the largest tubes of any recorded Ordovician *Girvanella.* Pia mentions a form *G. brainerdi* (Seeley) having a tube diameter of 50–100 μ. However, an examination of Seeley's original plates and material from his type locality indicate an alga of the *Sphaerocodium* type rather than a *Girvanella.*

This species occurs in loose masses and in thick coatings and nodular masses associated with *Girvanella problematica.* It is much less common in the Tasmanian collection than the two species previously described.

Occurrence and types.—Holotype: U.T.G.D. 25043a: Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania.

Syntype: U.T.G.D. 25084a: as holotype.

Phylum MOLLUSCA
Class GASTEROPODA
Superfamily MACLURITACEA
GENUS MACLURITES Lesueur, 1818.

Diagnosis.—Large, hyperstrophic shells with all whorls visible on flat lower side and a deep, often wide umbilicus on convex upper side; operculum a heavy, horn-shaped or flattened plate, which if horn-shaped has rugose projections on inner side for muscle attachment; ornamentation growth-lines and in some species revolving striae or grooves (Knight et al., 1944).

This genus is very widespread in the Ordovician system. It occurs in the Baltic, the British Isles, the Arctic, North America, Argentina, China, the northern Shan States, and Australia. It was recorded for the first time from Australia by Opik (Stevens, 1952), who noted its presence in limestones from Cliefden Caves, near Orange, New South Wales, where it is associated with a rich shelly fauna. It is also known from Tasmania.

MACLURITES FLORENTINENSIS
Banks & Johnson, n. sp.
Pl. 74, fig. 1,2,4,5,10.

Diagnosis.—*Maclurites* with a rate of increase corresponding to a tangential angle of 83°, approximately a trapezoidal whorl section, fine radial ornament only, and an apical angle of about 332°.

Description.—The holotype is a partial internal mould, the depressed apex being filled with limestone, the upper surface being an internal mould and the lower surface retaining some of the shelly material recrystallized. The specimen is 9.16 cm. in maximum diameter, and 2.90 cm. in maximum height. The shell is 0.26 cm. thick at the periphery close to the aperture.

The lower surface is slightly convex, the umbilical angle being approximately 184°. On this surface the whorls are almost flat, the sutures being very slightly impressed.

An ornament of very fine lines of growth occurs on this surface, the lines being very low and close together and making no impression on the internal mould which is smooth. The growth lines sweep back toward the apex from the inner suture of the whorl and then cross the main body of the whorl in a line which is gently concave to the aperture. One of the syntypes (U.T.G.D. 25707, pl. 74, fig. 2) shows that this ornament continues over the upper surface of the whorl at least to the edge of the apical depression.

There are six whorls, of which four are readily visible on the lower surface and, when the central part is moistened and examined closely, two more are revealed. The nucleoconch is 1 mm. in diameter. Measurements were made of the radii of successive whorls along two radial lines approximately at right angles, with the following results:

(a)	0.05	0.09	0.17	0.59	1.19	2.48+ cm.	
(b)	0.05	0.06(?)	0.11	0.31	0.60	1.69	3.77+ cm.
(c)	0.05	0.09	0.13	0.35	0.74	1.89	3.82+ cm.
(d)	0.05	0.07	0.23	0.47	1.10	2.63	5.51+ cm.

The measurements were made in 1/128th inches and converted to millimetres. The radii of the outside whorl are all a little less than the true radii because some or all of the outside wall is missing. It will be noticed that there are anomalies in these measurements, due to difficulties of measuring near the nucleoconch and to slight shearing.

From these measurements, the ratio r_{x+1}/r_x, where r_x is the radius of whorl number x, and r_{x+1} the radius of whorl number $x+1$ measured along the same line, was calculated for as many whorls as possible. The mean of these ratios was then found according to the formula

$$m = \Sigma fV/n$$

where m is the mean, f is the number of ratios falling in a class with the median value of V, and n the total number of ratios, and found to be 2.205. For any one set of measurements along a radius of the shell successive radii plotted on logarithmic scale against whorl number on arithmetic scale fell on approximately straight lines (text-fig. 2b), thus showing the rate of increase to be logarithmic and the spiral an equiangular one (see Darcy Thompson, 1942, Chapt. XI). As the umbilical angle of the holotype is 184° (i.e., the semi-angle of the enveloping cone is 88°), the angle of the spiral can be determined (see Thompson, 1952, p. 771) from the formula

$$\cot \alpha = \frac{\log 2.205}{2\pi \sin 88° \log e},$$

and is found to be approximately 82° 58′.

The whorl section of the holotype cannot be determined with any accuracy but the syntypes show that it is essentially a trapezohedron with the corners considerably rounded. The angle between the parallel sides and the flat base of the whorl is 46° (approximately) in the holotype, but varies from 44° to 56° in the syntypes. The fourth side of the trapezohedron, the upper and inner side, is not revealed in the holotype, but is shown in the syntypes to be from 14° to 16° from vertical. In the outer whorls the uppermost corner of the trapezohedron is more angular than in the younger whorls and forms a rather sharp shoulder to the apical depression.

Although the apical depression ("umbilicus" of authors) cannot be observed in

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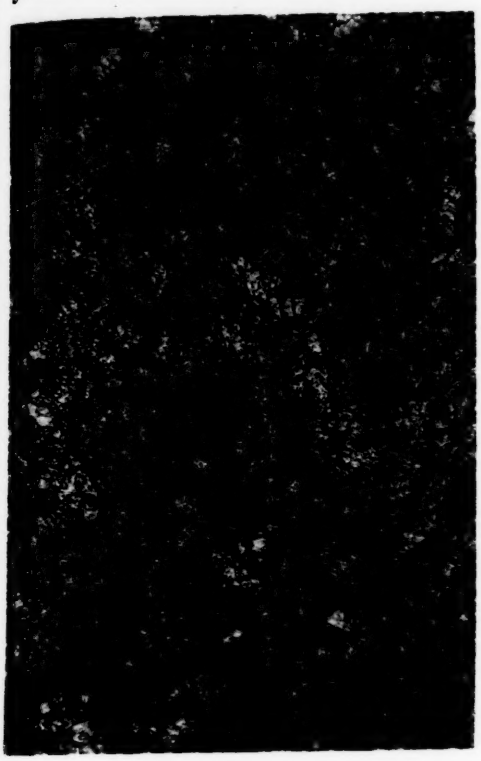
EXPLANATION OF PLATE 73

FIG. 1—*Girvanella problematica*, Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. U.T.G.D. 25045a. ×100.

2—*Girvanella grandis*, holotype, Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. U.T.G.D. 25043a. ×100.

3—*Girvanella tasmaniaensis*, holotype, Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. U.T.G.D. 25041b. ×100.

4—*Girvanella grandis* and *G. problematica*, Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. U.T.G.D. 25043a. ×100.



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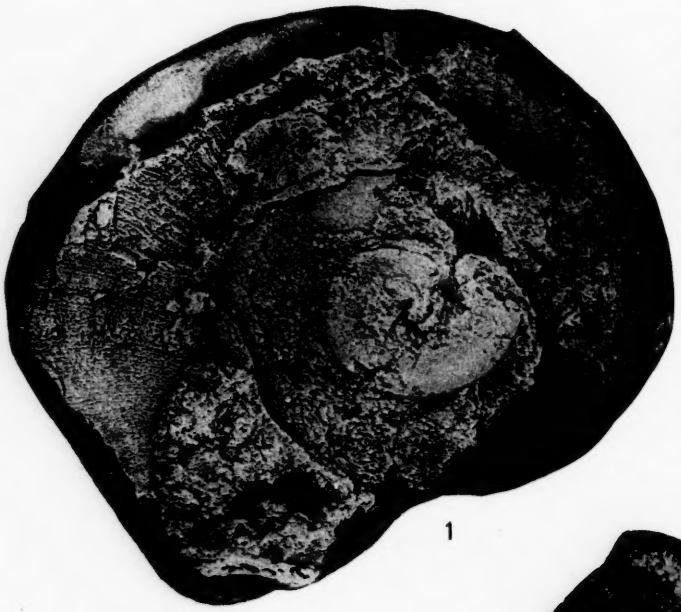
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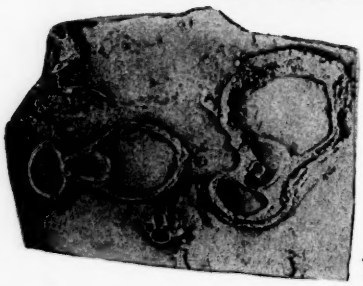
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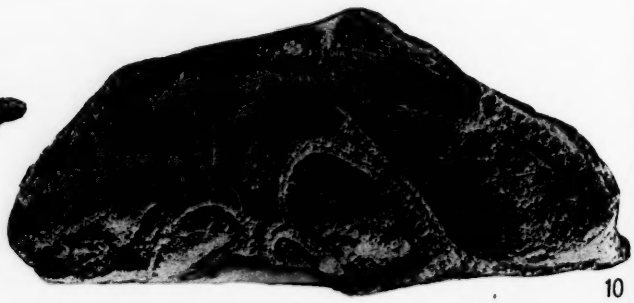
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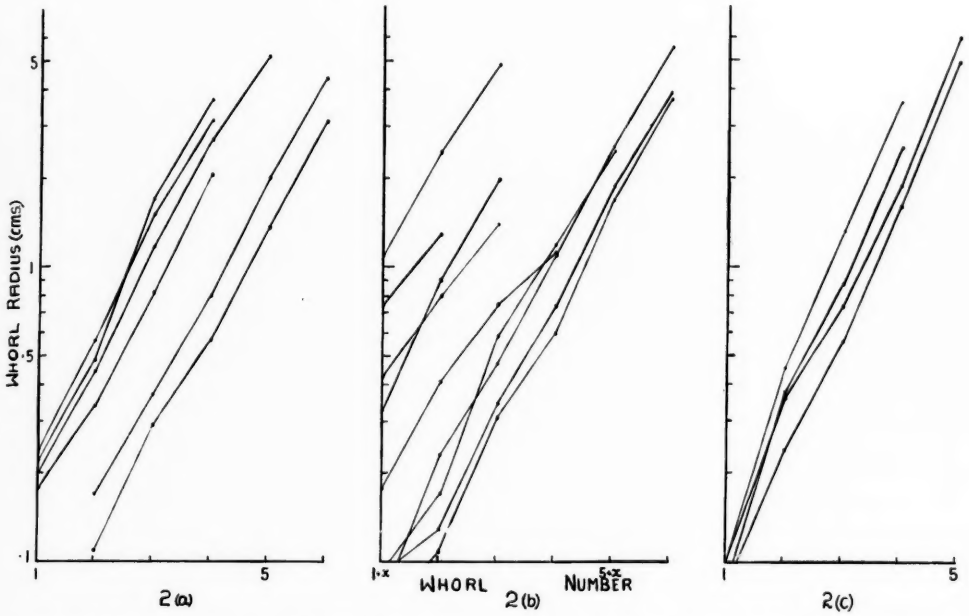

TEXT-FIG. *2*—Graph of whorl radius against whorl number in: (a) types of *Maclurites magnus;* (b) types of *M. florentinensis;* (c) types of *M. logani.*

EXPLANATION OF PLATE 74

FIG. *1*—*Maclurites florentinensis*, holotype, basal view; note ornament; U.T.G.D. 21718; Gordon River Limestone, Ordovician; Benjamin, Florentine Valley, near Maydena, Tasmania, ×1.

2—*M. florentinensis*, syntype, side view; note ornament; U.T.G.D. 25707; Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. ×1.

3—*Maclurites* sp., a flat operculum; note boss for muscle attachment in top centre; U.T.G.D. 25311; Gordon River Limestone, Ordovician; Goliath Cement Co. Quarry, Railton, Tasmania. ×1.

4—*M. florentinensis*, syntype, showing profile and narrow apical depression; U.T.G.D. 25708; Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania, ×1.

5—*M. florentinensis*, natural section of syntype, showing profile and narrow apical depression; U.T.G.D. 26907; Gordon River Limestone, Ordovician; Cashions Creek Florentine Valley, near Maydena, Tasmania. ×1.

6—*Maclurites* sp., horn-shaped operculum; side view showing boss for muscle attachment; U.T.G.D. 26910; Gordon River Limestone, Ordovician; Goliath Cement Co. Quarry, Railton, Tasmania. ×1.

7—Bellerophontids, other gasteropods, *Girvanella* and sponges associated with *M. florentinensis* (not shown in figure); U.T.G.D. 26912; Gordon River Limestone, Ordovician; Benjamin, Florentine Valley, near Maydena, Tasmania. ×½.

8—*Maclurites* sp., horn-shaped operculum, showing coiling of boss for muscle attachment; U.T.G.D. 26910; Gordon River Limestone, Ordovician; Goliath Cement Co. Quarry, Railton, Tasmania. ×1.

9—*Maclurites* sp., operculum, U.T.G.D. 26911; Gordon River Limestone, Ordovician; Goliath Cement Co. Quarry, Railton, Tasmania. ×1.

10—*M. florentinensis*, syntype, natural section, showing whorl profile, and narrow apical depression; U.T.G.D. 25033; Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, near Maydena, Tasmania. ×1.

the holotype, syntypes reveal that it is comparatively narrow and that within it the sutures are initially quite deeply impressed, later becoming deeply channeled. The apical angle could be measured in four of the synthypes and was found to be about 332°, so that the apical depression is quite narrow. Wherever it could be observed, the nucleoconch lies at the base of the apical depression and forms part of the lower surface.

on semi-logarithmic graph paper and found to fall on an essentially straight line for each species. The lines for *M. florentinensis*, *M. magnus*, and many other species are essentially parallel; one exception, *M. logani*, however, has a markedly steeper slope (see text-fig. 2). In an attempt to treat the rate of increase somewhat statistically, the ratio r_{x+1}/r_x was determined for as many species as possible, with the following results:

	Mean	Standard Deviation	Range	Number Measured	Spiral Angle	Source
1. *M. magnus*	2.386	±0.354	1.96–3.40	32	82° 45′	Knight, 1941, Plate 64, figures 1, 2 and 4.
2. *M. magnus*	2.607	±0.670	1.53–5.57	88		Specimens in Harvard Museum of Comparative Zoology, and illustrations of *M. magnus* from North America.
3. *M. magnus*	2.548	±0.586	1.53–5.57	120		Includes 1 and 2
4. *M. florentinensis*	2.138	±0.503	1.20–3.46	33	83° 04′	Holotype and syntypes.
5. *M. logani*	3.06		2.09–4.75	14	80° 44′	Salter, 1859.
6. *M. bigsbyi*	2.32		2.09–2.66	6		Whitfield, 1882, and Ulrich & Schofield, 1897.
7. *M. bigsbyi*	3.42		2.72–5.22	8		Endo, 1932.

Variations shown by syntypes.—Most of these are listed in Table 1.

It will be seen that the height varies from less than a third to over a half of the diameter. Although there are insufficient figures for significance, there is a suggestion that the height increases more slowly than the diameter.

The mean figure for the ratio r_{x+1}/r_x for the specimens available was calculated and found to be 2.138. The average umbilical angle is 190°. Based on these two figures, the average spiral angle is 83° 04′.

The apical angle varies from 328° to 334°, with an average for four specimens of almost 332.°

Opercula have not yet been found in the Florentine Valley.

Comparisons.—Many authors refer to the rate of increase as a specific character, but rarely quote figures in their descriptions. To determine relationships of the Tasmanian specimens, their successive whorl radii were measured as previously explained, and compared with radii measured in specimens or illustrations of as many other *Maclurites* spp. as the senior author was able to find. Radii of successive whorls were then plotted

From these figures it will be seen that *M. florentinensis* may have a slightly lower rate of increase than *M. magnus*, but there are hardly enough measurements of either to determine this finally. Similarly, *M. logani* seems to increase still more rapidly than *M. magnus*, but again more measurements are needed. American specimens of *M. bigsbyi* are quite close to *M. magnus* as far as coiling is concerned, but the Chinese specimens (Endo, 1932) seem distinctly different.

The ornament of *M. florentinensis* is very similar to that of *M. magnus* and a number of other species but differs markedly from that of *M. manitobensis* and somewhat from that of *M. bigsbyi*, which has fine revolving lines. Because the umbilical angle of *M. magnus* varies from 177° to 199° and that of most species is between 180° and 190°, this character cannot be considered diagnostic. Another character used by some authors to distinguish species is whorl section. In this *M. florentinensis* is closest to *M. magnus* and *M. bigsbyi*, and in peripheral whorl profile sometimes approaches *M. cuneata* although it differs in over-all whorl profile.

TABLE 1—MEASUREMENTS OF SYNTYPES OF *Maclurites florentinensis*

Diameter (cms.)	Height / Diameter	Radii (cms.)	$\frac{r_{x+1}}{r_x}$	Umbilical angle	ρ	β
Holotype: 9.16	0.319			184°	46°	
Syntypes: 8.02	0.461	1.07 2.42 4.84	2.26 2.0		45°	166°
		0.73 1.27	1.73	189°	56°	167°
		0.32 0.89 1.98	2.82 2.22			
3.93	0.50			186°	45° 49°	166°
4.72	0.521	0.42 0.79 1.41	1.90 1.78	194°	44°	
3.83	0.524	0.18 0.41 0.73 1.11	2.33 1.76 1.51	198°	54°	164°

r_x, r_{x+1} = radii of successive whorls; ρ = angle between flat lower surface and parallel sides of trapezohedral whorl section; and β = half of apical angle.

Thus, as far as rate of increase and whorl profile are concerned the Tasmanian specimens could be either *M. magnus* or *M. bigsbyi*, but in one important respect, the apical angle, they differ from both species. In those specimens or illustrations of *M. magnus* which show this feature, the angle was found to be 304°, 319°, and 308°, each of which is somewhat less than the angle shown by *M. florentinensis;* in *M. bigsbyi*, angles of 306°, 316,° and 295° were measured. In respect to this character only *M. acuminata* (328°), *M. manitobensis* (326°) and *M. cuneata* (355° and 336°)) are at all close to *M. florentinensis*, most of the others being similar to, or less than *M. magnus*.

Thus, in summary, *M. florentinensis* resembles *M. magnus* more than any other species but differs from it in having the apical angle about 20° greater and perhaps also in the slightly smaller rate of increase.

Occurrence and types.—Holotype; U.T.-G.D. 21718: Gordon River Limestone, Ordovician; Benjamin, Florentine Valley, Tasmania; Pl. 74, fig. 1. Paratypes, U.T.-G.D. 25033: Gordon River Limestone, Ordovician; Cashions Creek, Florentine Valley, Tasmania; Pl. 74 fig. 10.; U.T.G.D. 25707: Same locality as 25033; Pl. 74 fig. 2.; U.T.G.D. 25708: Same locality as 25033; Pl. 74 fig. 4; U.T.G.D. 26906: Same locality as holotype; unfigured; U.T.G.D. 26907: same locality as 25033; Pl. 74, fig. 5; U.T.G.D. 26908: same locality as holotype; unfigured; U.T.G.D. 26909: same locality as holotype; unfigured.

MACLURITES sp.

Although sections of *Maclurites* have been seen in a number of places as detailed earlier, only at Railton could specimens be collected. One of these (U.T.G.D. 25334) consists of a piece of blue-grey limestone broken in two. The fossil shows the pseudo-sinistral coiling and a deep, rather wide apical depression. The upper edge of the whorl is sharply angulated and the angle is distinctly sharper than in *M. florentinensis*. Unfortunately, insufficient characters are shown to allow a specific determination. The other specimens collected at Railton are the opercula illustrated (pl. 74, fig. 3,6,8,9). Two, U.T.G.D. 26910 (pl. 74, fig. 6,8) and U.T.G.D. 26911 (pl. 74, fig. 9), are horn-shaped. Specimen U.T.G.D. 26910 has a more or less triangular section, 3.06 cm. in length and 1.75 cm. in width; the horn is 2.32 cm. in length, with the longest side of the horn being 4.11 cm., the apex being situated almost at one side of the horn. There is no sign of coiling in the main body of the operculum, but this may be due to the beekitisation of the specimen. The abapical surface is somewhat hollowed. On this surface is a ridge for muscular attachment, which arises from the rim of the operculum at one end of the shortest side, and, coiling dextrally, rises rapidly to its

highest point, 0.77 cm. above the surface (pl. 74, fig. 6), and then falls slowly towards the shortest side. No rugosites are present on it. The other hornshaped operculum (U.T.G.D. 26911) is incomplete and shows only a slight sign of the ridge for muscle attachment (at the angle between the two arms in pl. 74, fig. 9).

Also from Railton is a flat operculum (U.T.G.D. 25331, pl. 74, fig. 3). This was not completely exposed by acid treatment which revealed part of the flat base of a *Maclurites* in the same piece of limestone. The preserved part is 4.54 cm. long and about 2.60 cm. wide. The apex, which lies slightly outside the plane of the rim and overlaps the margin of it considerably, has a slight sinistral twist when viewed from above. The most prominent feature of the operculum is the projection for muscular attachment, which from within the angle under the apex rises rapidly to a ridge 0.77 cm. below the plane of the rim, and then slopes downward towards the centre of the operculum. The highest preserved part of this ridge is 0.78 cm. long and 0.42 cm. wide, and oval in section. There are no rugosites preserved. Insufficient features were available to allow specific identification, and although in flatness it resembles *M. logani*, its other features are dissimilar.

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MANUSCRIPT RECEIVED AUGUST 13, 1956

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 641–647, 2 TEXT-FIG., MAY 1957

THE VALUE OF PLEISTOCENE MOLLUSKS AS INDEX FOSSILS OF WISCONSIN SUB-AGES IN NEBRASKA

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ABSTRACT—Individual species or assemblages of species of mollusks are not considered to be indices of Wisconsin sub-ages in Nebraska because almost all the forms are found in continuous succession in "Peorian" and post-"Peorian" Pleistocene sediments.

INTRODUCTION

THE purpose of this article is to present information on the stratigraphic distribution of Pleistocene mollusks in the "Peorian" and post-"Peorian" Pleistocene sediments of Nebraska and to consider the value of these mollusks as index fossils. The data presented comprise a synthesis of the findings of Howard Stacy (1949), Philip Seff (1952), William Wakely (1954), and the writer (1956A) in their studies of Pleistocene environmental conditions.

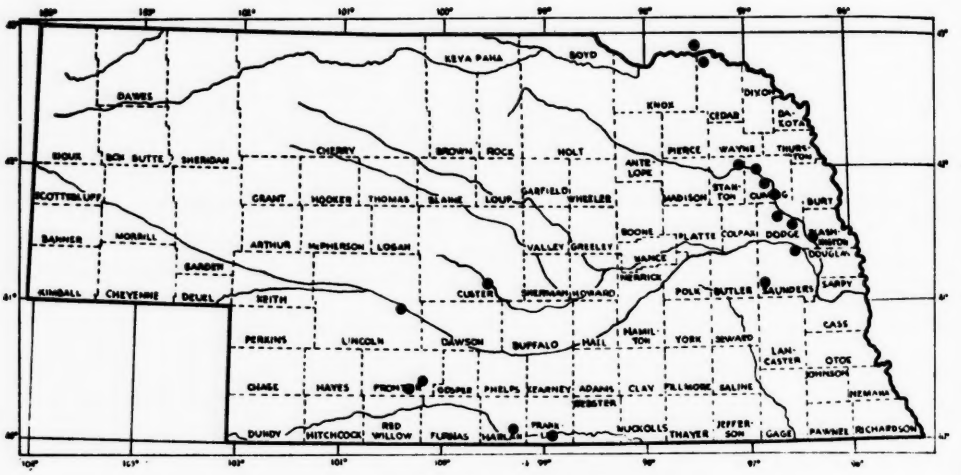
Prior to 1949, Pleistocene mollusks were only occasionally collected in Nebraska. The most important of these early collections came from isolated units in the Scottsbluff Bison Quarry (Schultz and Eiseley, 1935), the "Loup River" and "Sheridan" beds, and the Niobrara Valley deposits (Lugn, 1935). The mollusks found in these deposits were identified by the late Frank C. Baker, and are now part of the invertebrate collection at the University of Nebraska State Museum in Lincoln, Nebraska.

In 1949 systematic collecting of entire terrace fills rather than isolated units was started in Nebraska. Since that time stratigraphic collections of Pleistocene mollusks have been obtained from Cedar, Cuming, Custer, Dodge, Franklin, Frontier, Harlan, Lincoln, Saunders, and Stanton Counties, Nebraska; and Yankton County, South Dakota (Stacy, 1949; Seff, 1952; Wakely, 1954; Frankel, 1956A. See text-Fig. 1). Materials from which the mollusks were gathered vary from gravels to alluvial and aeolian silts, and therefore encompass a great variety of environments. Because the entire sequence of Wisconsin sediments was collected in most of these areas, the stratigraphic distribution of the mollusks contained in these materials is farily well known.

The value of Pleistocene mollusks as "index" fossils has long been a subject of controversy. As early as 1913 B. Shimek stated that these mollusks do not enable us to determine the age of Pleistocene formations. He restated this belief as late as 1930. F. C. Baker in 1920 held essentially the same view as Shimek, but in 1931 decided that certain species found in the Pleistocene deposits were distinctive and could be utilized to determine ages of certain Pleistocene deposits. In 1944, R. J. Russell claimed that the mollusks were incorporated into loessic sediments during mass movement and could indicate no other than Recent or late Quaternary age.

In recent years A. B. Leonard (1950, 1951, 1952; Frye & Leonard, 1952) has utilized mollusk assemblages for the zonation of "Peorian" loess and has described typical molluscan faunas from the Nebraskan, Kansan, Illinoian, and Wisconsin deposts in Kansas. In addition, Leonard has examined many deposits in surrounding states and has utilized mollusk assemblages to determine the age of the deposits. In 1952 Frye and Leonard utilized the data obtained in Kansas to make sweeping statements concerning the time of extinction of large numbers of mollusks in the Great Plains region.

Unfortunately, work in Kansas has mainly been concentrated in examination of Nebraskan, Kansan, and Illinoian alluvial deposits and Peoria and Bignell loess deposits, and not the younger Wisconsin terrace-fill deposits, but in Nebraska, for the most part, just the opposite has been done. However, Frye and Leonard (1952, p. 166) report that preliminary studies of the



TEXT-FIG. *1*—Map showing mollusk-collecting areas.

terrance-fill faunas in Kansas ". . . provided a means of determining age and correlation of sediments in local areas where other stratigraphic criteria are lacking or unsatisfactory."

Even though work in these two states has been done in different types of deposits, certain similarities and dissimilarities are striking. In the main, the chief disagreement at present appears to be the time at which certain species became extinct in the Great Plains and mid-continent regions, and the potentiality of utilizing mollusks as indices of different sub-ages of Wisconsin sediments.

TERRACE FILL DEPOSITS IN NEBRASKA

The mollusks discussed in this report were collected from terrace fills developed along the major river valleys or their tributaries. Terraces and terrace fills in Nebraska were first recognized by Darton (1903) and Alden (1924, 1932). In recent years studies were made by Schultz and Stout (1945, 1948); Lueninghoener (1947); Frankforter (1950); and Schultz, Lueninghoener, and Frankforter (1948, 1951). The 1951 report of Schultz et al., a synthesis of the information obtained from earlier studies, is an attempt to correlate terraces and terrace fill development with specific Pleistocene ages and sub-ages.

Although seven terraces and terrace fills (numbered 5, 4, 3, 2B, 2A, 1, and 0 by Schultz & Stout, 1945, 1948 and by Schultz Lueninghoener, & Frankforter, 1951) are recognized in Nebraska, only five will be discussed. These are fills 4, 3, 2 complex, 1, and 0. Terrace 5 is not considered because it is predominantly composed of pre-"Peorian" Pleistocene materials and because little is known of the mollusks, since collecting has been quite limited. Terrace 2B and 2A are grouped as terrace 2 complex in this paper because it is usually impossible to distinguish them in the field, since they often occur at the same elevation.

The bulk of the sediments in the successive terrace fills considered in this paper (4, 3, 2 complex, 1, and 0) become progressively younger, although there is a great overlapping of materials. Unless eroded, the older terraces will usually contain a capping of sediments equivalent in age to those in the younger fills, and each younger fill will contain only a portion of the sedimentary record (see text-Fig. 2).

The oldest material considered in this report is "Peorian" loess and alluvial silt. In Nebraska the basal part of this formation probably includes the Farmdale loess and alluvial silts recognized farther east (Leighton & Willman, 1949, 1950). In many places the "Peorian" is the youngest formation in terrace 4 fill. In some areas it is capped by Bignell loess (Schultz & Stout, 1945), which is separated from the "Peorian" by the Brady soil zone (Schultz & Stout,

1945, 1948). The formations which underlie the "Peorian" in terrace 4 fill range in age from Nebraskan to Illinoian. Systematic collecting from these units has just been started in Nebraska, and not much is known of their faunal content. No radiocarbon datings of the "Peorian" are available in Nebraska. If it is equivalent to the "Peorian" and Farmdale in the Mississippi Valley, then a relative age assignment of from 25,000 to 17,000 years (Horberg, 1955) may be applicable. Likewise, no datings for the Brady soil or Bignell loess are available from this area. If Horberg's tentative datings can be applied to this area, the Brady material is from 17,000 to 14,000 years old, and the Bignell materials successively younger.

No radiocarbon datings are available for terrace 3 fill. The basal unit, the Todd Valley formation, is considered to be late Iowan in age (Lugn, 1935; Lueninghoener, 1947). The bulk of the alluvial silt and loess overlying the Todd Valley formation is believed to be Tazewell in age (Schultz et al., 1951). The Brady soil zone and Bignell loess are recognized in the upper part of this fill. Therefore, there appears to be considerable overlap between the materials in this fill and the materials in the upper part of terrace 4 fill.

Radiocarbon datings are available only for the terrace 2A fill portion of the terrace 2 complex. These vary from $10,493 \pm 1500$ to $8,274 \pm 500$ years in age (Schultz et al., 1951, p. 34). As these datings come from the lower part of the fill, it suggests a range of from 12,000 to 8,000 years for the lower portions of terrace 2A fill, and successively younger ages for the overlying materials.

Radiocarbon dating from a hearth in terrace 1 fill, Cedar Canyon, Sioux County, Nebraska, averaged $2,147 \pm 150$ years in age (Schultz et al., 1951, p. 37). C. B. Schultz, Director of the University of Nebraska State Museum, suggests (personal communication) an age of from 3,500 to 1,900 years for the lower part of terrace 1 fill and successively younger ages for the upper materials.

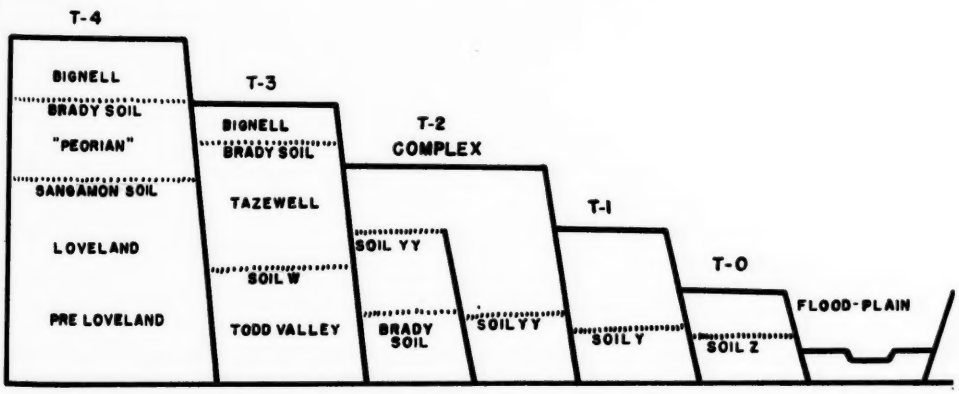
No radiocarbon datings are available for terrace 0 fill. A tentative dating of from 1,000 to 900 years is suggested by Schultz et al. (1951, p. 37).

STRATIGRAPHIC PALEONTOLOGY

Fossils become useful in stratigraphic studies only if they occur in readily determinable characteristic assemblages which have a limited vertical (time) range and a wide geographic distribution in the area under consideration; these characteristic forms should also occur abundantly, otherwise they are mere paleontological curiosities.

Having stated the most important criteria for "index" fossils, let us consider each point separately, as concerns the "Peorian" and post-"Peorian" mollusks.

Abundance.—In general, mollusks are relatively abundant in these sediments. Leonard (1952, p. 11, 14) discusses the distribution of mollusks in the Peoria loess of Kansas



TEXT-FIG. 2—Terrace fills of Nebraska. Stylized diagram showing stratigraphic and topographic relationships of the different fills. (Modified from Schultz, Lueninghoener, & Frankforter, 1951.)

and indicates that the number of shells per cubic foot ranges from 0 to over 5,000. The writer has found that the same situation exists in the "Peorian" and post-"Peorian" sediments of Nebraska. In certain areas and in certain units mollusks are extremely abundant, and in others extremely rare. High and low population densities, in many instances, were probably due to favorable and unfavorable environmental conditions. In other instances, absence, or small numbers, of mollusks is probably due to the destruction of shells by leaching.

R. J. Russell's (1944) hypothesis that the mollusks found in loess are recent, or at oldest, late Quaternary forms, which were incorporated into sediment during mass movement, appears to have found little support. In order to explain the absence of snails in alluvial terrace materials and their presence in loess, Russell concludes (1944, p. 21–22):

> Those finding their way into loess are preserved in a calcareous environment, but those getting into other materials are subjected to leaching and disappear promptly.

This is contrary to findings in Nebraska and at Yankton, South Dakota, where mollusks are found in all types of alluvial sediments, and in many places rival or surpass the number found in loess. Once entombed in sediment, the preservation or destruction of molluks (like other fossils) depends on the duration and severity of leaching that the material is subjected to, and not to the origin of the material.

Geographic Distribution.—All the mollusks found in these sediments are extant in some portion of the United States, although many are not at present found in the Great Plains or mid-continent areas. (For distribution of living mollusks refer to Pilsbry, 1948; Leonard, 1952.) The reports of Shimek (1898, 1913, 1930), Baker (1920, 1928, 1930, 1931, 1936), Cameron (1940), Stacy (1949), Leonard (1950, 1952), Seff (1952), Frye & Leonard (1952), Wakely (1954), Taylor & Hibbard (1955), and Frankel (1956A) indicate that many mollusks which once inhabited large portions of the Great Plains, mid-continent, and Mississippi Valley regions are no longer part of the indigenous fauna. Their distribution in the past, like that of today, was controlled by environmental conditions. It is concluded that these forms were widely distributed in the area under consideration, and therefore fulfill another of the critical requirements for "index" fossils.

Vertical Distribution.—As stated in the previous paragraph, all the mollusks which were found in the "Peorian" and post-"Peorian" sediments are extant in some region of the United States. Most of them are found in Aftonian or Yarmouth sediments, and a few are known to occur in the Pliocene Laverne formation (Leonard, 1950, 1952). Because most of them are known from early to late Pleistocene time, they do not meet the limited vertical range requirements of index fossils of the different "Peorian" and post-"Peorian" sub-ages.

There are, however, other means by which these species may be utilized as index fossils. If certain subspecies or varieties were restricted to particular formations or time rock units they would be valuable. Baker (1931) reported that several forms appear to be specifically or varietally distinct from their living relatives, and thus reversed his earlier opinion (Baker, 1920) that the modern forms are practically the same as the species which lived during the Pleistocene. Shimek (1930) observing the trend towards recognition of subspecies and varieties, reiterates his earlier opinion (Shimek, 1913) that none of the loess species are wholly extinct, and that the variation in forms found in the Mississippi Valley loess was probably very similar to the variation which occurs today.

The individuals of each species examined by the writer exhibited considerable variation; however, relatively the same range of variation occurred in each locality where the mollusks were found in abundance. There does not appear to be a vertical limitation to the different varieties found. Therefore, it is not deemed possible to distinguish rock or time rock units in Nebraska by utilizing subspecies or varieties. Although most of the mollusks found in the "Peorian" and post-"Peorian" sediments have too long a time range (i.e., Pliocene, or lower Pleistocene, to Recent) to be indices in the ordinary sense, when the United States as a whole is considered, they might meet the requirement if particular forms were to become extinct or migrate into restricted areas during specific

times. Thus, since the possibility of utilizing certain species or subspecies (or varieties) as general age determinants over large areas is ruled out, it is now opportune to determine whether the presence or absence of any forms or assemblages of forms in restricted areas will enable the identification of rock or time rock units.

In recent years A. B. Leonard (1951, 1952) has utilized typical mollusk assemblages for the zonation of the Peoria silt in Kansas. The writer (1956B) has noted that it is impractical to do the same in Nebraska because many of the "key" species in these assemblages in Kansas (e.g. *Succinea avara, S. grosvenori, S. ovalis, Lymnaea parva,* and *Vertigo modesta*) are found throughout the "Peorian" sediments. Further study in Nebraska may indicate that many other species restricted to certain zones in Kansas occur throughout the "Peorian "materials.

Turning now to the post-"Peorian" sediments there is much contradiction in the findings in Nebraska and Kansas. Frye and Leonard (1952, p. 180) conclude:

> The great populations of *Discus, Pupilla, Vertigo* and *Vallonia gracilicosta,* together with less widespread populations of *Hendersonia occulta, Columella alticola, Striatura milium, Euconulus fulvus,* and several other species, completely vanished from the Great Plains at the close of Tazewellian or during Bradyan time.

This conclusion cannot be accepted for or applied to Nebraska because *Columella alticola, Discus cronkhitei, D. shimeki, Euconulus fulvus, Striatura milium, Vallonia gracilicosta* and *Vertigo modesta* have been found in the post-"Peorian" terrace fills in the Great Plains province (Stacy, 1949; Seff, 1952; Frankel, 1956A).

A check list of fossil mollusks arranged according to their stratigraphic distribution in Kansas prepared by Frye and Leonard (1952, p. 182–183) allows one to continue the comparison of "Peorian" and post-"Peorian" mollusk ranges in Kansas and Nebraska even further. The data for Kansas are based on the above-mentioned list. For Nebraska (and Yankton, South Dakota) the data are comprised of a compliation of the findings of Stacy (1949), Seff (1952), Wakely (1954) and Frankel (1956A).

The youngest stratigraphic unit in which the following mollusks are reported in Kansas is the upper Peoria silt; in Nebraska they are found throughout the post-"Peorian" terrace fills (terrace 2 complex, 1, and 0 fills): *Carychium exiguum, Discus cronkhitei, D. shimeki, Deroceras laeve, Euconulus fulvus, Gastrocopta holzingeri, Helicoidiscus singleyanus, Pupilla blandi, P. muscorum, Retinella electrina, Striatura milium, Vallonia gracilicosta, Vertigo modesta, Vertigo gouldi paradoxa, Zonitoides arboreous.*

In Kansas the reported stratigraphic limit of *Lymnaea parva* and *Succinea avara* is the lower Peoria silt. In Nebraska they are found throughout the "Peorian" formation and also the post-"Peorian" terrace fills (terrace 2 complex, 1, and 0 fills).

Gastrocopta tappaniana, Pupoides albilabris, Physa anatina, and *Helisoma antrosa* reportedly make their final appearance in Kansas during the Crete-Loveland interval. In Nebraska all are known to occur in post-"Peorian" terrace fills. Except for *Heilsoma antrosa,* which at present has only been found in terrace 1 and 0 fills, the others are known from terrace 2 complex, 1, and 0 fills. *Pupoides albilabris* has also been found in "Peorian" sediments.

The youngest stratigraphic unit in which *Gastrocopta contracta, G. procera, Valvata tricarinata, Ferrissia parallela,* and *Pisidium compressum* are reported in Kansas is the Sappa formation. In Nebraska all of them are found in the post-"Peorian" terrace 2 complex and 1 fills. *Gastrocopta contracta* and *Pisidium compressum* are in addition found in terrace 3 and 0 fills, and *Gastrocopta procera* has been found in terrace 0 fill. Further study will probably show that these forms are found in continuous succession in the terrace fills.

CONCLUSIONS

The conclusion reached by Stacy (1949), Seff (1952), Wakely (1954), and Frankel (1956A) is that the Pleistocene mollusks mentioned in this paper can in no way be utilized as indices of Wisconsin sub-ages or older ages in Nebraska. Although a list of the species from any single collecting locale would show that many forms are missing, composite lists compiled by combining the faunas of relatively the same age, but from different environments, indicate that practically all forms are present.

Why the difference in the faunas found in Kansas and Nebraska? The question is very difficult to analyze. Although less area has been studied in Nebraska, a greater variety of environments probably was encountered in the study of terrace fill materials than has been encountered in Kansas where terrace fill studies have just commenced. Perhaps further studies in Kansas will indicate that species deemed to have become extinct at an earlier time persisted throughout the Pleistocene in areas where conditions were favorable, or perhaps, they will show that these forms really did become extinct.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 648-650, 5 TEXT-FIG., MAY 1957

NOTES ON THE GASTROPOD *PALLISERIA ROBUSTA* WILSON[1]

ELLIS L. YOCHELSON[2]

ABSTRACT—*Palliseria robusta* Wilson is informally redescribed from additional specimens collected by members of the Geological Survey of Canada, in Alberta, Canada. This species is compared with *Palliseria longwelli* (Kirk), and on the basis of the new material it is concluded that the two named species are actually conspecific. The Canadian and American specimens do not come from beds of markedly different age.

MORE than three decades ago, Wilson (1924) described the gastropod *Palliseria*, with *P. robusta* as the type and only known species. At that time, it was thought that the specimens came from the Beaverfoot formation of British Columbia and were of Richmond (Late Ordovician) age. Subsequently, Wilson (1926) redescribed the genus and other elements of the so-called Beaverfoot fauna.

Four years later, Kirk (1930) described the genus *Mitrospira*, with *M. longwelli* as the type and only known species. The genus was described from the upper part of the Pogonip group (then Pogonip limestone) in Nevada from beds dated as Chazy in age, a term then used for post-Beekmantown Early Ordovician. The upper part of the Pogonip has been distinguished as the Antelope Valley limestone (Nolan, Merriam, and Williams, 1956, p. 25, 28, 29). The Antelope Valley limestone is divided into four faunal zones, the next to the oldest being the zone of *Mitrospira*. Cooper (1956, p. 126, chart 1) places this same zone, which he calls *Palliseria*, in his Whiterock stage of the Lower Ordovician.

Knight (1941) redescribed and refigured both Kirk's and Wilson's species. Subsequently, he (Knight, 1944, p. 469) considered *Mitrospira* to be a junior subjective synonym of *Palliseria*. On the basis of the published record, Knight gave the range of *Palliseria* as Ordovician, inasmuch as one of the two included species was supposedly of Middle Ordovician (Chazy) age, and the other thought to be of Late Ordovician (Richmond) age. However, both Kirk and Cooper (in Duncan, 1956) agreed that Chazy as used in the West by U. S. Geological Survey authors indicates late Early Ordovician, rather than early Middle Ordovician.

Extensive field work in western Canada by members of the Geological Survey of Canada has produced new information about the Ordovician beds of that region. Harker, Hutchinson, and McLaren (1954, p. 52) report that several faunas were mixed in the orginal collection that provided the specimens on which *Palliseria* was based. Rather than being from beds of Richmond age, the genus almost certainly occurs only in beds of late Early or earliest Middle Ordovician age. The anomalous difference in age of the western Canada and Nevada specimens is thus canceled.

In connection with study of the Ordovician in western Canada Dr. Peter Harker collected additional specimens of *Palliseria* from Nigel Peak in Alberta, some 125 miles north-northwest of Palliser Pass, the type locality of *P. robusta*. Through the courtesy of the Geological Survey of Canada, I have had the privilege of studying the types of this species and the new specimens. The specimens from Nigel Peak are all incomplete, but in many respects they are superior to the types. Five of the specimens showing significant morphologic features are illustrated. Accordingly, it seems appropriate to modify the original description in certain features.

Wilson (1924, p. 151) noted that the silicified shell appeared to be composed of three layers, with the middle layer being the weakest and most porous of the three. An alternative interpretation is that the shell is composed of a relatively thin outer layer and a thicker inner layer. Study of silicified specimens of *Straparollus* (*Euomphalus*), a relatively thick-shelled gastropod from the Permian of west Texas, has shown that the

[1] Publication authorized by the Director, U. S. Geological Survey.

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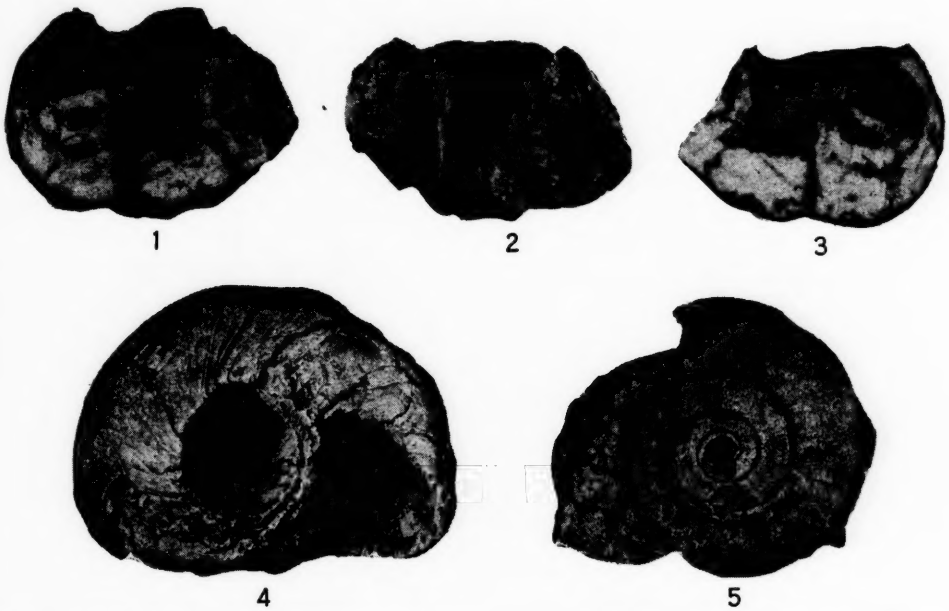
silicification process may produce peculiarities within the shell. In these forms and in many brachiopods, it is not uncommon for the outer part of the outer shell layer and the inner shell layer to be silicified, with the space between being only partially silcified, or remaining calcitic. Should the thin outer silicified crust be broken, the middle portion may be dissolved away completely or partly by acid during preparation. Wilson (1924, p. 150) described a broad flattened band as occurring on the outer whorl face, but it seems clear that the bordering carinae and the flattened area are all secondary features produced by partial silicification. The new specimens show that the outer whorl face is generally well rounded, becoming more flattened near the basal suture.

The types also show closely spaced, strongly impressed growth lines ornamenting the surface. Silicified specimens that show similar features are known from the Permian. These lines are attributed to original differential silicification along the growth lines, accentuated during the etching process. On Permian specimens, comparable distinct lines are found when the outer part of the outer shell layer is not preserved. Several of the Nigel Peak specimens (for example, see text-fig. 4—5) show an essentially smooth outer surface with relatively faint growth lines, and this is unquestionably the way the shell appeared in life.

Because of the poor preservation of the types, little has been published on the nature of the whorl juncture and the whorl profile within the depressed spire. One incomplete individual from Nigel Peak (text-fig. 2) shows that in an intermediate growth stage, the suture is distinct, with the whorl suture rising nearly vertical from it. Near mid-whorl the whorl surface curves outward. The upper third of this surface is straight, inclined outward probably about 12 to 25 degrees from vertical. With increasing maturity, the inclination of the upper part



TEXT-FIG. *1–5—Palliseria robusta* Wilson. All hypotypes are figured at natural size and are from Geological Survey of Canada locality 19741, collected by P. Harker from a 60 foot thick dolomite bed, 760 feet below Mt. Wilson quartzite, on the west slope of Nigel Peak, Jasper National Park, Alberta, Canada. *1*, natural section, showing shape of whorls, G.S.C. No. 13,428. *2*, natural section, showing curvature of whorls within depressed spire, G.S.C. No. 13,429. *3*, polished section, the section being cut near, but not at, the apex, G.S.C. No. 13,430. *4*, top view showing growth lines, depressed spire and sharp circumspiral ridge, G.S.C. No. 13,431. *5*, basal view, showing protruding rounded base, G.S.C. No. 13,432.

of this inner whorl surface becomes slightly less steep. The same specimen shows the mature whorl overhanging the earlier whorl, but the specimen is crushed and this feature is attributed to distortion. The types and another Nigel Peak specimen show that each succeeding whorl is set back within this depressed spire, so that a stair step profile is produced.

Field work indicates that the specimens from Palliser Pass and Nigel Peak probably come from the same stratigraphic level. Insofar as the specimens from the two areas can be compared, they are similar, and I consider them to be conspecific. The Nigel Peak specimens have also been compared with Kirk's types of *Mitrospira longwelli* and additional well preserved specimens from Nevada. In all details the similarity is remarkable, and *Mitrospira longwelli* Kirk is considered to be a junior subjective synonym of *P. robusta* Wilson. The latest correlations indicate that in the United States at least, the species is limited to beds of late Early Ordovician age.

In his original description, Kirk (1930, p. 3) notes that Ulrich identified specimens of *Mitrospira* from the Simpson group of Middle Ordovician age in Oklahoma and from Ordovician beds at Phillipsburg, Canada. The Oklahoma specimens have not been found, but certain Phillipsburg specimens labelled *Mitrospira* by Ulrich appear to be deformed thick-shelled specimens of *Maclurites* from which most of the shell on the base has been removed. The deformed steinkerns thus appear to have a slightly protruding base.

Although the nucleus and earliest whorls are still unknown, one specimen from Nevada gives us a better idea of their relative size. The specimen, not illustrated, has all but 1.1 mm. of the whorls preserved. Beyond this point coiling of the shell is typically hyperstrophic. Another specimen confirms the size of this earliest portion, but silicification is so coarse that the character of this portion cannot be determined.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 651–653, 2 TEXT-FIG., MAY 1957

NONMARINE PELECYPOD (*NIPPONONAIA ASINARIA*) FROM THE LOWER CRETACEOUS OF COLORADO[1]

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ABSTRACT—A unionid pelecypod from the Burro Canyon formation of Colorado is assigned, as *Nippononaia asinaria*, to a genus hitherto reported only from Japan. It is unlike recorded American forms.

IN THIS paper a pelecypod from the freshwater Burro Canyon formation of western Colorado is described and assigned to a genus originally described from Japan. It is perhaps unusual to make such an assignment, but the characters of the shells are so close that no other course seems rational.

The Burro Canyon formation, along with the Lower Blairmore formation of Alberta, the Kootenai formation of Montana, the Cloverly formation of Wyoming, and contemporaneous units, is generally assigned on the basis of the contained flora to the Lower Cretaceous Aptian stage. The present fossil is associated with such species as *Protelliptio douglassi* (Stanton) and *Lampsilis farri* Stanton.

Genus NIPPONONAIA Suzuki 1941

Unio (*Nippononaia*) Suzuki, 1941, p. 410–413, text-fig. 1–3.
Plicatounio (*Nippononaia*) Suzuki, 1943, p. 196, 211.
Plicatounio (*Nippononaia*) Suzuki, 1949, p. 95, 119.

Suzuki (1941, p. 411) defined this genus as follows:

> Shell of medium size, elongated subelliptical in outline, anterior part usually shorter than posterior; surface ornamented by numerous radiating ribs, middle ones of which converge to form acute V's on a line across the beak; inner side of ventral margin finely crenulated; hinge teeth of left valve typical of genus in the presence of two short and narrow cardinals and two short and smooth laterals.
>
> Type.—*Unio* (*Nippononaia*) *ryosekiana* Suzuki, new subgenus and new species.

In 1943 and again in 1949 Suzuki placed *Nippononaia* as a subgenus under *Plicatounio* Kobayashi and Suzuki (1936, p. 250).

Suzuki considered as distinctive "the V-shaped radial ornament covering the whole disc" and "the crenulated inner side of the ventral margin," and called attention to similar ornament in some genera of the living South American subfamily Hyriinae and in *Trigonioides kodairai* Kobayashi and Suzuki (1936, p. 249).

The horizon of the type species was originally given as the "Ryoseki group, the basal part of the Early Cretaceous Monobegawa series." In a compilation of the Cretaceous of Japan (Matsumoto and others, 1953) the only use of either generic or specific name, as *Plicatounio* (*Nipponaia* [sic]) *ryosekianus*, is in a diagram (p. 123) showing the ranges of species. The range of *ryosekianus* is given by a broken line as through the Kochian series, and on a later page (p. 200) the Kochian series is indicated as equivalent to the Berriasian and Valanginian stages of the European sequence. *Nippononaia* is therefore still viewed as of an age early in the Early Cretaceous.

NIPPONONAIA ASINARIA Reeside, n. sp.
Text-fig. 1,2

Diagnosis.—This species is sharply marked by its small size, broad-oval form, and particularly by the sculpture, which consists of two unequal sets of radial ribs that form chevrons on the middle of the valve and of transverse ribs anteriorly and posteriorly.

Name.—*Asinarius*, pertaining to an ass (Spanish: *burro*).

Material.—The description is based on five internal molds on which the external sculpture has been secondarily impressed and two partial molds of the exterior. One of the molds, selected as the holotype, displays both valves and the other specimens

[1] Publication authorized by the Director, U. S. Geological Survey.

TEXT-FIG. *1*—*Nippononaia asinaria* Reeside, n. sp., ×1½. *1*, drawing of the holotype, a mold of the interior of both valves, on which the external sculpture has been impressed.

are single valves, four left and two right.

Description.—The general form of the shell, as preserved, in lateral view is broad-oval, and the valves appear to have been shallow, though it is difficult to estimate the effect of compression on the shell. The beaks are situated about two-fifths the length behind the anterior margin. The holotype mold retains an impression of the exterior of the tip of the beak of the right valve. The dorsal margin is nearly straight; the anterior, ventral, and posterior margins are broadly rounded.

The external sculpture of the shell is strong. Two sets of straight, or nearly straight, even, flattened ribs pass from the dorsal margin to the ventral margin, spreading somewhat as they descend; interspaces are nearly as wide as the ribs. Along a line extending posteriorly at about 60° to the dorsal margin from a point just behind the beaks, these sets of ribs meet to form three or four chevrons pointing ventrally. On the specimens in hand there are 12 or 13 ribs in the anterior set and 9 or 10 in the posterior set. On each valve approximately the posterior one-sixth is occupied by faintly curved, nearly transverse ribs which may extend with much reduced length along the dorsal margin to, or nearly to, the beak, though this is not well shown by the specimens in hand. The impression of the tip of the right valve of the holotype shows very fine radial ribs except on the posterior side, where there are fine transverse ribs like those on the hinge margin. Similar but shorter transverse ribs occupy the upper part of the anterior margin.

The hinge consists of a long posterior lateral tooth in the right valve, opposed by a pair of posterior laterals in the left valve; and a pair of anterior teeth (pseudocardinals?) in the right valve, opposed by a long anterior tooth in the left valve. As preserved, the right posterior lateral shows faint irregular cross-striations and the space between the right anterior pair shows faint corrugations suggesting that the left anterior lateral in good condition may show cross-striations. No other dentition is evident in the specimens available.

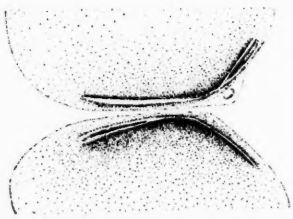
Muscle scars and pallial line have not been detected, nor can the character of the interior ventral margin be seen in any available specimen.

The holotype is 26 mm. long and 16 mm. high, with a depth, as preserved, of about 2 mm. in each valve. Another valve is 19 mm. long, 11.5 mm. high, and 2 mm. deep.

Locality.—NE¼ NW¼ NE¼ sec. 11, T. 43, N., R. 18 W., San Miguel County, Colorado (USGS 26021). Burro Canyon formation. Collector, Daniel R. Shawe, 1955.

Types.—Holotypes, USNM 128366; paratypes, USNM 128367a–f.

Remarks.—*N. asinaria* resembles *N. ryosekiana* (Suzuki) closely in the general form, the character of the external ornament, and in the hinge features, except that the left anterior (pseudocardinal?) tooth appears to be single. There seems no doubt that they are congeneric. *N. asinaria* differs from *N. ryosekiana* in the number of ribs per valve and in the distribution of them. Suzuki's type figure shows about 23 anterior ribs and 20 posterior ribs, twice as many as in *N. asinaria*. The anterior transverse ribs are



TEXT-FIG. *2*—Diagrammatic drawing of a rubber cast of the hinge of the holotype, USNM 128366, ×1½.

more prominent than in *N. asinaria* and the posterior transverse ribs are presumably less prominent, though they are not seen in the figure of the possibly incomplete type of *N. ryosekiana*.

N. asinaria differs markedly from any North American species known to the writer in the ornament of the valves. Some living groups, such as *Quincuncina* Ortmann, 1922, and a number of fossil forms variously referred to *Proparreysia*, *Quadrula*, and other genera, have a somewhat similar but more elaborate sculpture, tending to the formation of several lines of intersecting chevrons and nodose ornament where the ribs cross and tending to restriction of the sculpture to the apical part of the valve.

NIPPONONAIA sp.

In one small specimen preserving the internal mold of both valves in place and measuring 15 mm. long, 13 mm. high, and 7.5 mm. thick, the form is more nearly subtrigonal than oval and the rib count shows 16 ribs in the anterior set on each valve and 12 in the posterior set, though the general character of the shell is like that of *N. asinaria*. This specimen and another preserving a mold of part of a valve may represent a variant sufficiently different to deserve a distinctive name, but in the absence of adequate material may be referred to for the present as *Nippononaia* sp.

Specimens.—USNM 128365.

Locality.—Same as for *N. asinaria*.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 654–661, 1 TEXT-FIG., MAY 1957

PLIOCENE FRESH-WATER MOLLUSKS FROM NAVAJO COUNTY, ARIZONA

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ABSTRACT—Nine species of freshwater mollusks are recorded from the upper member of the Bidahochi formation in Navajo County, Arizona, two of which, *Lymnaea albiconica* and *L. dineana*, are new.

These mollusks and the directly associated mammals make up the White Cone local fauna, of Hemphillian age. This assemblage probably lived in a climate with summers cooler than those of the area today, in and around the shallow border of a large, permanent lake.

INTRODUCTION

LATE Tertiary nonmarine mollusks are known from only a few localities in the southwest United States. Those listed herein are the only ones known from Arizona, and so help to fill a large gap in knowledge of such faunas.

The U. S. Geological Survey is mapping the Navajo Indian Reservation in connection with ground-water studies. To obtain additional information about the Bidahochi formation J. W. Harshbarger, C. A. Repenning, and J. P. Akers of the Navajo Project, and J. F. Lance of the University of Arizona, visited White Cone Peak in July, 1953, together with a U. S. Geological Survey party led by J. B. Reeside, Jr. Members of the latter party included A. Calderón García, H. R. Christner, E. Rodriguez Santana, M. V. A. Sastry, and D. W. Taylor. Mollusks collected by these parties are the principal basis of this paper; the vertebrates from this and earlier collections are being studied by J. F. Lance.

Acknowledgments.—For opportunity to study the fossils and for aid in preparing the manuscript the author thanks J. W. Harshbarger, J. B. Reeside, Jr., and C. A. Repenning, U. S. Geological Survey; J. F. Lance, University of Arizona; and M. C. McKenna and D. E. Savage, University of California. The data on Sphaeriidae were contributed by H. B. Herrington, Keene, Ontario, Canada. The illustrations of shells are by Miss Joan Sischo, University of California; the detailed drawings by Miss Carolyn Bartlett, U. S. Geological Survey.

PREVIOUS PALEONTOLOGICAL WORK

Gregory (1917, p. 82) first reported mollusks from what is now termed the Bidahochi formation. He listed three genera without specific identifications from White Cone Peak, regarding the deposits as Tertiary. Reagan (1932, p. 257–258) reidentified and figured the forms reported by Gregory. Reagan dated the upper part of the Bidahochi formation as Pleistocene on the basis of his identifications of the mollusks.

Stirton (1936) described a beaver, the first vertebrate from the formation. It was also from White Cone Peak and considered middle Pliocene in age. Wood et al. (1941, p. 36 and chart) first used formally the term White Cone local fauna. It is applied here to the associated mollusks and vertebrates from the upper member of the Bidahochi formation at White Cone Peak.

Repenning and Irwin (1954) summarized geological information on the Bidahochi formation. Their paper should be consulted for information on composition and distribution of the formation, and for references to earlier geological work.

The molluscan material reported here consists of three collections: (1) the first collection, made by H. E. Gregory in 1911, and later recorded by him (Gregory, 1917, p. 82); (2) a small collection made by C. A. Repenning in 1950; and (3) the larger collection obtained by the U. S. Geological Survey parties listed above in 1953. Gregory's collection is U. S. Geological Survey Cenozoic locality 7415; the later collections are 19176.

Mollusks of White Cone local fauna

Pisidium compressum Prime
Sphaerium striatinum (Lamarck)
Valvata humeralis Say
Lymnaea albiconica Taylor, n. sp.
L. dineana Taylor, n. sp.
Helisoma subcrenatum (Carpenter)
Promenetus umbilicatellus (Cockerell)
Physa, 2 spp.

OCCURRENCE

The associated mammals and mollusks of the White Cone local fauna described here are from the upper member of the Bidahochi formation at White Cone Peak, sec. 12, T. 25 N., R. 21 E., 1½ mi. south of White Cone Trading Post, Navajo Co., Arizona. The locality is illustrated by Gregory (1917, pl. 14, fig. B). Although the Bidahochi formation is widely distributed in northeastern Arizona, mollusks have been found elsewhere only at the southern edge of Roberts Mesa, a short distance north of White Cone (C. A. Repenning, personal communication, 1956).

STRATIGRAPHY

The Bidahochi formation is divisible into three mappable members (Repenning and Irwin, 1954): a lower sedimentary member, a middle volcanic member composed of basaltic rocks which locally grade laterally into agglomerates, and an upper sedimentary member. The lower member consists of banded mudstones and argillaceous fine-grained sandstones of lacustrine origin. The upper member consists chiefly of cross-bedded argillaceous sandstone of fluvial origin. "Basaltic volcanic rocks were extruded in the Bidahochi area of deposition about the time that deposition of the mudstone of the lower member terminated and streams depositing the sandstone of the upper member advanced into the central parts of the area" (Repenning and Irwin, 1954, p. 1823).

All three members of the Bidahochi formation are present at White Cone Peak, and are readily discernible in the photograph published by Gregory (1917, pl. 14, fig. B). Shells were collected from several highly fossiliferous beds in the upper member of the formation. A few *Pisidium* specimens were taken from a well indurated sandstone near the top of the Peak; the other fossils are from lower horizons. Only a small percentage of the shells weather out unbroken, but exposures are sufficient to yield material adequate for identification. Geologic sections at White Cone Peak were given by Gregory (1917, p. 82) and Reagan (1932, p. 256).

AGE AND CORRELATION

The most recently published and most reliable date for the White Cone local fauna is Hemphillian (approximately middle Pliocene), assigned by Stirton (1936) on the basis of the beaver *Dipoides*. This age designation is supported by the additional mammalian material now known (J. F. Lance, 1954).

Molluscan evidence is slight, but tends to support the Hemphillian age indicated by the mammals. Five of the seven specifically identified forms are living species whose earliest known occurrence is in the White Cone local fauna. *Lymnaea dineana* is known only from White Cone. *L. albiconica* occurs also in the Clarendonian Laverne local fauna of Beaver County, Oklahoma, and in a Hemphillian assemblage in the upper part of the Teewinot formation of Jackson Hole, Wyoming.

The first age determination of White Cone mollusks was that by Reagan (1932, p. 358), who dated them as Pleistocene. Reidentification of the mollusks, and especially knowledge of the associated mammals, show the age to be greater than Reagan thought.

PALEOECOLOGY

1. *Inferences from lithology.*—The following statement was kindly supplied by C. A. Repenning, U. S. Geological Survey (personal communication):

> A consideration of the depositional history of the Bidahochi formation, as expressed by depositional structures and sorting and grain-size variations, indicates quite conclusively that the lower part of the formation represents deposition within a fairly large body of water. Lacustrine deposits grade upward into fluvial deposits, which make up most of the upper part of the Bidahochi.
>
> The Bidahochi mollusks, from White Cone, occur almost entirely in the zone of gradation between lacustrine deposits and those of fluvial origin. They are most prominent in argilla-

ceous sandstone beds where they are associated with abundant fish bones and occasional plant remains. Less commonly they are found, in a fragmentary state, in clean, well-sorted gently crossbedded sandstone.

The lithology of the fossiliferous beds and the depositional history of the entire formation seems to indicate quite conclusively that the mollusks lived in near-shore sheltered areas, such as a bay or a lagoon, where the water was relatively clean and the bottom quite sandy. Fragmental remains found in better sorted and gently cross-bedded sandstone beds may have been animals which either lived in more open nearshore areas that were subjected to mild wave action, or were washed into these areas from the sheltered lagoons. Their fragmentary nature is best explained by wave action, as are the cross-bedding and the better than average sorting of grains. The absence of fossils in the majority of the formation seems best explained by the muddy nature of the bottom in the deepest parts of the lake, where wave action was unable to winnow off the fines.

A few fossils have been found, along with terrestrial plant remains, in units which could be interpreted as sluggish-stream deposits, perhaps of a deltaic nature where the streams entered the quiet water. However, the majority of the streams which deposited the upper part of the Bidahochi formation seem to have been rather active as they deposited cross-bedded sands in their channels and argillaceous flat-bedded, fine-grained sands on their rather extensive flood plains. No invertebrate fossils have been found in these deposits, although they have been found to contain vertebrate remains and, on the flood plains, plants.

2. *Inferences from fossils.*—In the southwestern United States, *Valvata humeralis* and *Promenetus umbilicatellus* occur only in the higher mountain areas. This suggests that the summers were less warm than now at the time of burial of the shells.

Chart 1 summarizes the habitat indications of the mollusks of the White Cone local fauna. Two habitats are suggested: shallow pools or lagoons which dried up in the summer, inhabited by *Promenetus*, and the shallow border of a lake or protected situations at the edge of a stream. The water of the latter habitat was generally quiet, but the clams suggest some current or wave action and a sandy bottom.

CHART 1—SUMMARY OF HABITAT INDICATIONS OF MOLLUSKS OF THE WHITE CONE LOCAL FAUNA

Habitat	Species	Abundance
Temporary Pond	Promenetus umbilicatellus	Scarce
Permanent water, quiet or with slight current	Sphaerium striatinum	Scarce
	Pisidium compressum	Common
	Valvata humeralis	Rare
	Lymnaea dineana	Abundant
	Helisoma subcrenatum	Common
Uncertain	Lymnaea albiconica	Scarce
	Physa spp.	Rare

The combined evidence of lithologic features and the molluscan assemblage thus suggests that the White Cone mollusks lived chiefly in shallow embayments at the edge of a large lake. This habitat was protected from extensive wave or current action, but not so much so that silt or clay size particles accumulated to any great extent. The bottom was sandy, the water clear. The lake as a whole was a permanent body, but seasonal fluctuations caused the shallower pools at the edge to dry up.

The present distribution of some White Cone species, as well as the permanence of the lake, suggest that summers were less warm than now, and that annual rainfall also may have been greater.

The absence of land snails is somewhat puzzling. Possibly they were missed in collecting, but this seems unlikely. More probably there were few or no suitable habitats along the shore. If so, riparian vegetation would have been scanty, a condition suggesting the climate was semiarid (rather than arid as it is now) and that the lake's supply of water was derived largely from rainfall in the mountains.

SYSTEMATIC PALEONTOLOGY

Class PELECYPODA

Family SPHAERIIDAE

Genus SPHAERIUM Scopoli, 1777

SPHAERIUM STRIATINUM (Lamarck)

?Unio, Gregory, 1917, U. S. Geol. Survey Prof. Paper 93, p. 82.

The object figured by Reagan (1932, p. 257, pl. 1, fig. 1) as "*Unio*" is probably a pebble. It is not a unionid, but may conceivably be a mold of *Sphaerium*. No molds of any mollusks were found at White Cone by the writer, however.

The basis of Gregory's reference to *Unio* is uncertain. No pelecypods were found in his material in the U. S. Geological Survey collections.

The White Cone *Sphaerium* material is a long, heavy form approaching the form *solidulum* Prime. The species has a wide geographic range and varying habitat, but requires a permanent water body with slight current and a fairly firm bottom. It is thus found in perennial creeks, rivers, and lakes, but not in swamps, ponds, or temporary streams; and in a gravel to fine sand bottom, but not one of mud or ooze.

Material.—U.S.G.S. 19176/1 (3 right valves, 2 left valves); Herrington collection (29 valves).

Genus PISIDIUM Pfeiffer, 1821

PISIDIUM COMPRESSUM Prime

The specimens do not belong to the "creek form" but are a long form. The ridges are not developed on the beaks.

Like *Sphaerium striatinum*, this species has a wide geographic and ecologic range. Its habitat is like that of the *Sphaerium*.

Material.—Herrington collection (5 whole specimens, 70 valves).

Class GASTROPODA

Family VALVATIDAE

Genus VALVATA Müller, 1774

VALVATA HUMERALIS Say

Reference of the White Cone material to one of the several described subspecies of *Valvata humeralis* is impracticable. Of the four specimens collected two are fragmentary, and none clearly fits one subspecies as against another.

The White Cone specimens agree with *V. h. humeralis* Say (Pilsbry, 1904, p. 778, pl. 52, fig. 9,12,12a) in size and shape, except that they lack the subsutural flattening. Preserved sculpture is typical also, with the exception noted below. *V. h. densestriata* Pilsbry (1934, p. 566, pl. 21, fig. 12,12a) was distinguished from the typical subspecies by its unflattened whorls and sculpture of "close, fine threads." One White Cone specimen shows such sculpture from 2 to 2½ whorls, but the rest is typical of *V. h. humeralis*. Topotypes of *V. h. californica* Pilsbry differ from the other subspecies by the very low spire, wide umbilicus, sculpture of growth lines only, and unflattened whorls. The White Cone specimens differ from these in their higher spire and narrower umbilicus.

Unreliable records and the lack of a review of *Valvata humeralis* make possible only general statements about the distribution and range of its subspecies. It seems established that the species has a wide range in the western United States and northern Mexico. *V. h. humeralis* is known from central and northeastern Mexico (Pilsbry, 1904, p. 778; Hinckley, 1907, p. 79). *V. h. californica* is known from Southern California north and northeastward (Hannibal, 1910, p. 105–106); records of *V. humeralis* from New Mexico (Pilsbry, 1906, p. 130; Pilsbry and Ferriss, 1909, p. 104) may be referable to it also. *V. h. humeralis* is known fossil only from Pleistocene beds near Mexico City (Morrison, 1945, p. 21). *V. h. californica* is reported from the Pliocene near Collinston, Utah (Chamberlin and Berry, 1933, p. 29) and in the Kettleman Hills, California (Pilsbry, 1934, p. 566). *V. h. densestriata* is known only from the Pliocene of the Kettleman Hills (Pilsbry, 1934, p. 566) and late Pleistocene beds in Siskiyou Co., California (Baker, 1942, p. 131).

Valvata is restricted to permanent water, and in Southern California lives only in high, cool mountain lakes.

Material.—U.S.G.S. 19176/5 (4).

Family LYMNAEIDAE

Genus LYMNAEA Lamarck, 1799

Subgenus STAGNICOLA Jeffreys, 1830

LYMNAEA ALBICONICA[1] Taylor, n. sp.

Text-fig. 1,—1–3

L. [*Lymnaea*] (*Stagnicola*) sp., Taylor, 1954, Univ. Mich. Mus. Zool. Occas. Paper 557, p. 12.

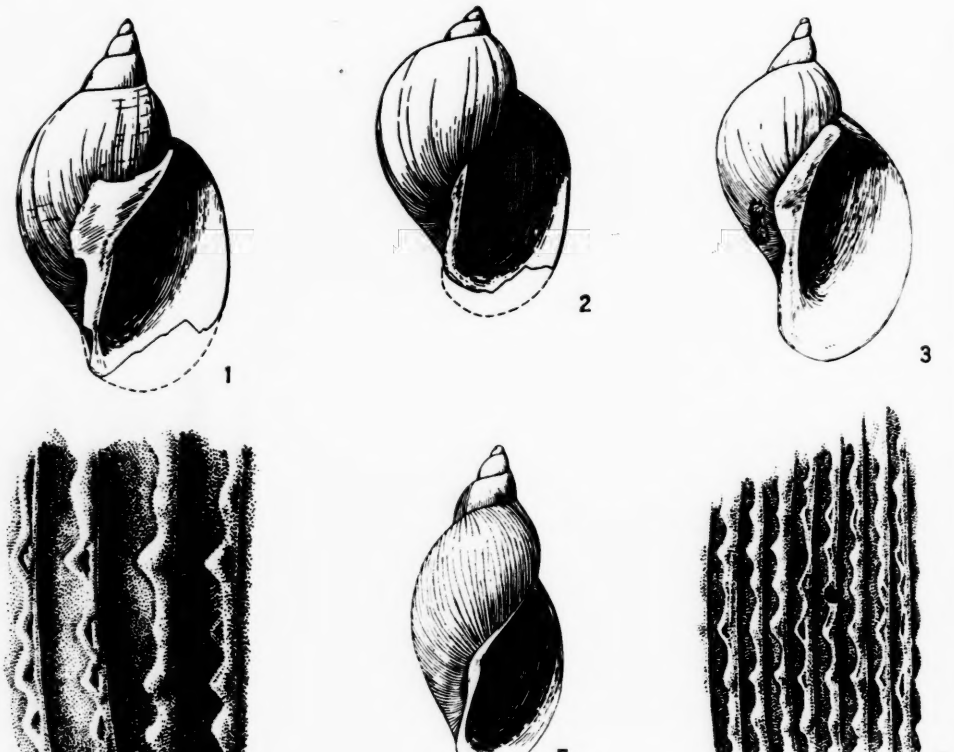
Lymnaea n. sp., Taylor, 1956, Wyoming Geol. Assoc. Guidebook 11, p. 123, fig. 2,8; Love, 1956, *ibid.*, p. 92; Merritt, 1956, *ibid.*, p. 119.

Holotype.—562081 U. S. National Museum. Navajo Co., Arizona. Middle Pliocene White Cone local fauna, Bidahochi formation. White Cone Peak, sec. 12, T. 25 N., R. 21 E., 1½ miles south of White Cone Trading Post.

Diagnosis.—A *Stagnicola* of the *palustris* group, distinguished by its sculpture of fine, regular, node-bearing axial riblets.

Description.—Shell elongately ovate, of

[1] Latin *albus*, white, and *conus*, a cone, in reference to the locality from which this species is described.



EXPLANATION OF TEXT-FIG. *1*

FIG. *1–3*—*Lymnaea dineana* Taylor, n. sp. White Cone local fauna, Hemphillian, Arizona; × about 2.5 *1*, figured specimen, U.S.N.M. 562086; *2*, figured specimen, U.S.N.M. 562085; *3*, holotype, U.S.N.M. 562084, length 18.1 mm.

4–6—*Lymnaea albaconica* Taylor, n. sp. White Cone local fauna, Hemphillian, Arizona; *4*, detail of sculpture above posterior end of aperture of adult specimen, U.S.N.M. 562082; the nodes on the axial riblets are hollow and show a pattern of open triangles when worn; *5*, holotype, U.S.N.M. 562081, length, 15.2 mm.; *6*, detail of sculpture from immature specimen, U.S.N.M 562083.

about 4½ strongly convex whorls with a well impressed suture. Sculpture of numerous, regular, fine axial riblets, slightly protractive toward the suture, one-fourth to one-fifth the width of their interspaces. Riblets nearly straight, or bearing spirally arranged arcuate nodes on their distal sides. Aperture narrowly ovate, rounded anteriorly, almost right-angled posteriorly. Narrow umbilicus covered by thick, reflected parietal lip.

Measurements (*mm.*).—Holotype length, 15.2; width, 7.7; length aperture, 8.5; width aperture, 4.3; whorls 4¼. A larger but imperfect specimen (U.S.N.M. 562082) would have measured if whole: length, 20; width, 8.5; whorls 4¾.

Variation.—The most variable character is sculpture. The axial riblets are of fairly constant spacing and prominence, but vary considerably in form. They may be nearly straight, or appear finely waved. The waving is not a sinuation of the riblets, however, but results from the accretion *on the distal side only* of spirally arranged arcuate nodes. The proximal side of a riblet with these nodes is thus straight, while the distal side is strongly undulate.

Remarks.—*Lymnaea albiconica* is scarcely distinguishable in shape and size from shorter, more globose forms of *Lymnaea palustris* (Müller). It is markedly distinct from that species and from all known *Lymnaea* by its unique sculpture.

Three fragmentary specimens (University of Michigan Museum of Zoology 181256) from the Clarendonian Laverne local fauna of Oklahoma probably represent *Lymnaea albiconica*. They have only the earliest whorls (up to 3¾) and show the characteristic sculpture, but have less globose spire whorls. The date of this assemblage is established by a mammalian fauna; see Hibbard (1951) for references to earlier literature.

A series of eight specimens (USGS 19106/2) from the upper part of the Teewinot formation in Jackson Hole, Wyoming, shows the same sculpture and size as the White Cone specimens, but the spire whorls are less convex and the sutures shallower. Such differences are found within living species, however, and do not suggest the Wyoming and Arizona specimens are specifically different. The Hemphillian age of this material is established by undescribed mammals in U. S. Geological Survey collection (cf. Love, 1956, p. 91).

Material.—U.S.G.S. 7415/1(1), 19176/2(1),19176/6(5), U.S.N.M.562081(1), 562082(1), 562083(1).

Subgenus PSEUDOSUCCINEA Baker, 1908

LYMNAEA DINEANA[1] Taylor, n. sp.

Text-fig. 1,—4–6

Limnaea stagnalis appressa Say, Reagan, 1932, Kans, Acad. Sci. Trans., v. 35, p. 258, pl. 1, fig. 6–11; Hunt, 1956, U. S. Geol. Surv. Prof. Paper 279, p. 29.

Holotype.—562084 U. S. National Museum. Navajo Co., Ariz. Middle Pliocene White Cone local fauna, Bidahochi formation. White Cone Peak, sec. 12, T. 25 N., R. 21 E., 1½ miles south of White Cone Trading Post.

Diagnosis.—A *Pseudosuccinea* of relatively large size with a high, narrow spire.

Description.—Shell ovate to narrowly ovate, of up to about 5 whorls with a moderately high, narrow spire and relatively large, rapidly expanding body whorl. Suture slightly impressed, early whorls slightly convex, body whorl large, inflated. Sculpture of fine to coarse, irregular, wavy growth lines protractive toward the suture, retractive toward the base, cut by irregularly discontinuous incised spiral lines just below the suture. Aperture ovate, rounded and effuse anteriorly, approximately right-angled posteriorly. Narrow umbilicus covered nearly or entirely by frequently thick reflected parietal lip; columellar plait slight; columella nearly straight, parallel to longitudinal axis of shell.

Measurements (mm): Holotype length, 18.1; width, 10.8; length aperture, 11.7; width aperture, 5.5; whorls 4¼. Fragments indicate specimens at least 40 mm. long.

Variation.—Nearly 200 specimens were studied, mostly young or slightly incomplete. The spire varies from high and attenuate to short and conic, but most specimens have a moderately high, narrow spire. The shape of the whole shell varies correspondingly from narrowly acute-ovate to globose, with a very short spire and large body whorl. Spiral sculpture is absent to strong. Most specimens have 1–3 discontinuous, strongly incised lines slightly below the suture; additional lines which may be present all over the shell are shorter and less conspicuous.

Remarks.—*Lymnaea dineana* differs from *L. columella* in its larger size, higher and narrow spire, less conspicuous spiral sculpture, thicker shell, and nearly straight columella. Baker (1911, p. 166) said of *L. columella:* "the columellar region is so narrow and so peculiarly arched that a view may be taken from the base nearly to the apex. . . ." In *L. dineana* the columella is nearly straight, so that no such view is possible, and so that the columella is parallel to the longitudinal axis of the shell. In *L. columella* the parietal lip is oblique; in *L. dineana* not so.

Lymnaea (*Bulimnea*) *petaluma* Hanna (1923, p. 37) has a superficial resemblance to *L. dineana*. It differs in its more convex spire whorls, malleate surface, absence of spiral sculpture and unexpanded aperture.

In North America *Lymnaea columella*, the nearest relative to *L. dineana*, is found in the United States east of the High Plains,

[1] *Dine*, the Navajo name for themselves.

western Cuba, and central Mexico south to central America (Hubendick, 1951, p. 133).

The earliest previously recorded occurrence of *Lymnaea columella* is in the lower Pliocene Laverne local fauna of Oklahoma (Leonard and Franzen, 1944, p. 24).

"*Columella* is an inhabitant of ponds and streams where the water is more or less stagnant; a locality with an abundance of lily pads is particularly favorable; it is found also along the shore in shallow water in the vicinity of cat-tails (*Typha*) and other reeds, upon which it is often found. . . ." (Baker, 1911, p. 170).

Reagan (1932, p. 257) suggested that Gregory's reference (1917, p. 82) to *Physa* was based on the common *Lymnaea* at White Cone. Gregory's material contains *Physa* but no *Lymnaea*, so that I feel Reagan's suspicion was incorrect.

Material.—U.S.G.S. 19176/3 (7), 19176/7 (150), Stanford Univ., Paleo. Type Coll. 8355; U.S.N.M. 562084 (1), 562085 (1), 562086 (1).

Family PLANORBIDAE
Genus HELISOMA Swainson, 1840
Subgenus PIEROSOMA Dall, 1905
HELISOMA SUBCRENATUM (Carpenter)

Planorbis subcrenatus Carpenter, 1856, Proc. Zool. Soc., pt. 24, p. 220–221.
Helisoma subcrenatus (Carpenter) Baker, 1928, The Fresh Water Mollusca of Wisconsin, pt. 1, p. 333.
Planorbis trivolvis Say, Reagan, 1932, Kans. Acad. Sci., Trans., v. 35, p. 257, pl. 1, fig. 2–5.
Planorbis trivolis [sic] Say, Hunt, 1956, U. S. Geol. Surv. Prof. Paper 279, p. 29.

The present range of this species is in the Great Basin and Rocky Mountains, northward an uncertain extent.

Helisoma subcrenatum lives in quiet or slow-moving water, such as ponds, lakes, or quiet areas along streams.

Material.—U.S.G.S. 19176/4 (2), 19176/8 (23).

Genus PROMENETUS Baker, 1935
PROMENETUS UMBILICATELLUS (Cockerell)

Planorbis, Gregory, 1917, U. S. Geol. Surv. Prof. Paper 93, p. 82.

This species is now found in North America north of about the forty-first parallel from Nevada and Alaska east and southeast to western New York, and southward in the Rocky Mountains to New Mexico.

The previously recorded geologic distribution of the species is the upper Pliocene and Pleistocene of the High Plains; the earliest occurrence known up to now is in the lower upper Pliocene Saw Rock Canyon local fauna.

Promenetus umbilicatellus is characteristic of temporary pond habitats. According to Baker (1928, p. 384) it is rare in Wisconsin, but I found it common in drainage ditches and temporary ponds in northern Nebraska.

Material.—U.S.G.S. 7415/2 (7), 19176/9 (13).

Family PHYSIDAE
Genus PHYSA Draparnaud, 1801

Fragmentary material clearly represents two distinct species of *Physa* but is inadequate for reference to described species. The habitat is indicated as uncertain in chart 1, because different species live in a wide variety of environments.

PHYSA species a

Physa, Gregory, 1917, U. S. Geol. Surv. Prof. Paper 93, p. 82.

This is a species with a moderately high spire, like *P. anatina* Lea or *P. osculans* Haldeman.

Material.—U.S.G.S. 7415/3 (4).

PHYSA species b

A second species has an unusually blunt, depressed spire, similar to that of *P. fontinalis* (Linné) or of *P. skinneri* Taylor.

Material.—U.S.G.S. 7415/4 (1), 19176/10 (1).

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PROTOZOA AS A SEMANTIC PROBLEM

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INTRODUCTION

IN AN attempt to resolve a difficult taxonomic problem Moore (1954) has recreated the kingdom of Protista for the Treatise of Invertebrate Paleontology and this has stimulated both favorable and unfavorable reactions (Weller, 1955; Flower, 1956; Jones, 1956; Silva, 1956). It seems strange that this subject should arouse much interest among plaeontologists because the controversial "plant-animals" are among the rarest of all fossils. The paleontologists' chief concern in connection with this problem would seem to involve the placement of a few groups of fossils most of which customarily have been included in the Protozoa.

RECREATION OF PROTISTA

There is no point in completely reviewing the presentation of Moore's case, but several of his statements trouble me. Concerning the acellularity of the Protozoans he states (p. 591) that ". . . these *acellular* organisma persist throughout their existence as isolated *single cells;* they are *unicellular* as well as *acellular.*" (These and following italics are mine.)

He (p. 591) defines Protista as ". . . all *acellular* organisms, that is those possessing within a *single cell* total properties of life which may reproduce itself; . . . "

He defines (p. 591) plants and animals as:

> Members of the Plantae (Embryophyta) and Animalia (Metazoa), restricted by exclusion of acellular organisms now placed in Protista, are distinguished by their universally multicellular organization, with differentiation of functions among parts of such sort that the individual cells are interdependent. Isolated cells cannot survive and reproductive mechanisms are specialized. *The difference between plants and animals defined in this way is profound.*[!] *Unquestionably, such plants and animals are divergent evolutionary products of protistan ancestors.*

He suggest (p. 592) division of Protista into two distinct groups:

> One division which *must be considered more primitive,* is distinguished by the *lack of a well-organized nucleus in the cell,* even though some exhibit chromatin bodies that may represent a very simple type of nucleus.

And finally (p. 588):

> Since *many* fossils represent the "no man's land" that strides or lies closely adjacent to the broken down fence, the problem of revised classification is of interest to paleontologists.

There may be some who fully understand these matters but, alas, others like myself are not so sure. The foregoing quotations emphasize the problem of cellularity as related to Protozoans and only incidentally refer to the primitiveness of these forms. Protozoans are considered to be primitive and simple by most paleontologists, however (Flower, 1956, p. 700,703,706; Jones, 1956, p. 19), and the citation of numerous references certainly is unnecessary. This idea has resulted in several logical somersaults. For example, Flower states (p. 701), "If life had a common origin, it must be expected that such creatures [neither plants nor animals] must have existed in the past." And (p. 702), ". . . the Protista reflects one of the greatest truths; the unified origin of all organic life . . . "; (p. 703) "Physiologically, such organisms are potentially primitive, for the first life forms must of necessity have lived on inorganic substances."

If someone cares to question these great truths I shall be glad to listen.

WHAT IS WRONG?

I submit the question: Are the ideas variously expressed in the above quotations correct? If they are not, such statements proclaimed *ex cathedra* are dangerous because persons who have no ideas on the subject and are disinclined to analyse the problem for themselves are likely to accept the statements without reserve. Such apathy with regard to problems is undesirable and a discredit to science.

Paleontologists know Protozoans from their fossilized skeletal remains and these are only products of secondary metabolic activity. I admire persons who are able to solve fundamental problems on the basis of

such incomplete evidence even though my feeling is accompanied by confusion. I admit my debt to them, even if their conclusions are inaccurate, because they force me to think about a problem and to attempt a clarification of my own views.

The chief misconceptions, as I see them, in the foregoing quotations and other similar statements concern usage of the terms, *Protista*, *origin of life*, *animal*, *cellular*, *primitive*, and *simple*. They will be discussed in the reverse order.

PROTOZOANS AS SIMPLE ORGANISMS

Protozoans are not simple organisms, although they may be treated as being simple. For that matter, no simple organisms exist. *Paramecium*, with its cythopharynx, neuromotor system, and haemoglobin, is a far cry from being simple, as some persons apparently believe. We say that a machine is simple if it has few parts, but can we conclude that an organism is simple if it has few cells? Or if it is small in size? The business of living is equally serious for both man and amoeba, neither can lose more than one thing, its life. Both strive equally to live. Is it any simpler to live with an unconscious mechanism than with so-called intelligence? Is it simpler to induce an environment to make living possible, as viruses supposedly do, than to conform to an uncontrolled environment, as most organisms do?

These are simply rhetorical questions and I shall not provide your answers.

PROTOZOANS AS PRIMITIVE ORGANISMS

The misconception that protozoans are primitive organisms is widespread and of long standing. Zoologists no longer consider protozoans to be primitive (e.g. Dobell, 1911; Lwoff, 1951; Calkins, 1941; Hutner, 1955; etc.), but paleontologists as usual lag behind in biologic understanding. It is impossible to reconstruct the thought processes of others, but do those who regard protozoans as primitive imply that they include the *first* animals? Are they *ancient* and *archaic* organisms? Are they *primordial* organisms that have not evolved? Do they retain *persistent* characters? If the term "primitive" is used, these are its meanings according to Webster.

There are several reasons why protozoans might be considered primitive:

1. Because they commonly have been considered primitive in the past—this shows lack of progress.
2. Because one has not given the matter much consideration—this shows lack of thought.
3. Because of complete ignorance of protozoans—this shows lack of knowledge.
4. Because the word "primitive" is misused—this shows lack of understanding.

Perhaps there are other reasons that have not occurred to me.

PROTOZOANS AS CELLULAR ORGANISMS

A cell is one of the minute elementary structures composing the greater part of organic matter. Protozoans resemble cells but they are more properly noncellular organisms and not unicellular ones. Because protozoans possess no organs or systems, are they uni-organic and uni-systematic? The comparative sizes of protozoans and metazoans are not significant. An amoeba has been likened to a leucocyte and a flagellate to a spermatozoon but these comparisons are of doubtful application. A little consideration should convince anyone that there are no necessary relations between protozoans and the cells of metazoans. Among protozoan autotrophs there is gradation from acellularity to multicellularity (Metaphytes). There is no comparable situation among heterotrophs except for *Proterospongia*, which possesses both amoeboid and flagellate components and may be a connecting link between the choanoflagellates and sponges.

For further and more detailed discussion on cellularity and primitiveness of Protozoa I refer the interested reader to the brilliant work of Dobell (1911). Need I add that you will find it more sophisticated than my poor *exposé*.

PROTOZOANS AS ANIMALS

Animals have been defined in may ways by many persons. The definitions are usually lengthy and include descriptions of many characteristics. Most briefly an animal is an organism that is phagotrophic (Hutner, 1951), which means that it eats, and this implies the nature of its body walls, its

mobility, and so forth. Plants by negative definition are organisms that are not phagotrophic.

The absence of cellulose and lack of photosynthetic activity are characteristic of most animals but there are exceptions and nutritional requirement (or lack of it) is a much better criterion. Of course this causes difficulties for a paleontologist. The nutritional classification is superior when dealing with fungi, which otherwise would be only half plants because they lack photosynthetic activities. Bacteria of course are plants, in spite of the absence of photosynthesis. Tunicates in a nutritional classification, are animals in spite of their cellulose walls. Protozoans that possess neuromotor systems (e.g. *Paramecium multinucleatum* with longitudinal strands of intercilliary fibrils), and are strongly phagotrophic certainly are animals. It is only among the flagellates (and not all of them by any means) that the well known examples of ambiguous organisms occur. Remove these organisms from the Protozoa if you wish but admit that other protozoans are animals if they are phagotrophic.

PROTOZOANS AND THE ORIGIN OF LIFE

In his recent paper Flower (1956) places Protista at the base of the phylogenetic tree. He implies that plant-like organisms gave rise to animals, and indicated that plant-like organisms were the original "primitive?") organic group.

Whether the Metazoa originated from ancient organisms similar to those we know today is highly questionable. According to prevailing modern biologic theories, however, plants did not give rise to animals. In order to understand the problem it is necessary to refer to our definition of an animal as a phagotrophic organism.

Obviously manufacturing one's own food is somewhat more troublesome than just eating. To synthetize your food you have to be an autotroph—that means you must have a number of enzymes to help you out. Plants require these enzymes. Does this suggest that plants are simpler organisms than animals which only need to eat? The early organisms of this planet certainly were not complex enzyme carriers, probably they just ate available organic matter. Oparin (1938) suggests that there must have existed large quantities of organic matter before life originated and this theory is supported by most modern biologists. Unsaturated carbon compounds and the simpler (smaller molecular weight) hydrocarbons may have been produced by simple inorganic photo and chemosynthetic reactions. Because no destructive bacteria existed, "food" may have been abundant. With its gradual exhaustion, necessity for biologic chemosynthetic phototrophic activity originated. Further and more useful views on the origin of life will be found in an entertaining article by Wald (1955) in the Physics and Chemistry of Life.

PROTOZOANS AS PROTISTIDS

In general the purpose of any classification is to group together objects which are similar at least in one respect. In systematics the objective is a "natural" classification produced by grouping organisms that are similar in more than one respect thus reflecting their phylogeny. Phylogeny is reconstructed from theoretical prototypes, usually selected from a series of recent organisms, which can be arranged in a sequence from less to more advanced, or what is considered less or more advanced. But to consider the existing organisms as prototypes of other forms is not permissible. We cannot be sure that anything in a fossil record corresponds actually to those forms selected as prototypes; in fact, paleontological experience generally has proved such theoretical reconstruction erroneous. In the case at hand the earliest "Protista" are foraminifera which are highly complex and advanced protozoans, not closely related to any that can be called border-line plant-animal organisms.

Classification must present workable units, and has to show the relationship between these individual components. How are fungi related to foraminifera? How are diatoms to be classified? These groups are treated with relation to their size and their acellularity, which is meaningless at the levels of higher systematic categories.

It was consideration of size and "unicellularity" that caused Ernest Haeckel to create and von Siebold to accept the term Protista, and thus to lump together good

holozoic and holophytic organisms, and create the difficulty of differentiating between animals, plants, and protists.

Recently Moore (1954) has revived the term Protista to include the so-called doubtful forms, and unfortunately many which are not at all doubtful. He has done this with complete disregard of the fact that an acellular animal is an animal, and that an acellular plant is a plant. To assume that the affinity of bacteria and ciliates is much greater than the affinity of *Proterospongia* and sponges is a great error.

The kingdon Protista is a wildly divergent, and highly polyphyletic group. Most Protozoans and Protophytans are highly specialized forms, and they are clearly animals and plants. Only a very few are doubtful plants and animals. If we classify Protozoa according to their food requirements, we find that the Protozoan (animal) way of feeding is holozoic and that the Protophytan way is holophytic. But this is only a matter of definition; holozoic and holophytic mean animal- and plant-like respectively. On the other hand an earlier proposed definition would resolve this inconsistency by applying the term phagotrophic, and we would have good phagotrophic animals within the group Protozoa, and would exclude both those with chlorophyll, and those that are not phagotrophic. The best solution to the problem, therefore, would be simply to remove from the Protozoa all those forms that are not animals in the above-defined sense.

Moore (1954) divides Protista into Monera, without a well-defined nucleus, and Protoctista, with a well-defined nucleus (algae, protozoans, fungi, etc.), but this also seems to be in error. It is well known that the nucleus is composed of 2-desoxyribose nucleic acid (DNA), and that the cytoplasm possesses predominately ribose nucleic acid (RNA). It has been shown that, with the exception of a few viruses, no organism exists that is devoid of DNA. It is not at all important whether a nucleus is clearly visible if the material of which it is composed is present in large quantity (bacteria possess good nuclei and nuclear material). Thus it seems illogical to divide the kingdom on no more than our inability to clearly see the nucleus.

In summing up, we might say that recognition of Protista, although a brilliant work of imagination on the part of Haeckel, has little support in facts, and our knowledge of the forms included in the category, as it stands today, points in a different direction.

For criticism of a different nature see Weller (1955) and Silva (1956).

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CITATIONS AND REFERENCES IN THE JOURNAL OF PALEONTOLOGY

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ABSTRACT—Citations and references are important parts of the scientific article. Their accuracy is an obligation and standardization is a courtesy to readers of the Journal. Authors submitting manuscripts to the Journal of Paleontology must observe the recommended form and abbreviations in citations, text references, and synonymies.

INTRODUCTION

IN GENERAL your editor and his assistant have no wish to emulate that diabolical old scoundrel, Procrustes, who is said to have forcefully fitted unlucky passers-by to his iron bed, stretching those too short and lopping off projecting parts of those too long. Contributors to the Journal have rights. They may arrive at Accuracy-Brevity-Clarity by routes of their choice. We try to follow their wording and check on the destination. (Most authors are already so amply supplied with journalistic idiosyncrasies that we need not impose our own on them).

Citations and references are justifiable exceptions to the free style rule, or lack of rule. Readers find it easier to scan and to read scientific journals when each article conforms to a particular format. Standardization of citations is especially helpful in compiling a bibliography.

In addition, we are committed. The form of citations listed in a pamphlet published by the American Geological Institute has been adopted by editors of the Journal of Paleontology, American Journal of Science, Journal of Geology, Bulletin of the Geological Society of America, and U. S. Geological Survey publications. This form is based on that given in a paper entitled "Abbreviations used in publications of the U. S. Geological Survey." The rules and abbreviations will be incorporated in the revised edition of "Suggestions to authors," now in preparation.

CITATIONS

Citations never contain too much information. A complete citation is the rare joy of the librarian, who spends many unrewarded hours searching for volumes listed cryptically or inaccurately. On his recent visit, one of our colleagues from South America told about his experiences in building up a departmental library. Many out-of-print articles were ordered on microfilm from the Library of Congress according to bibliographic entires. On more than one occasion, upon receiving the microfilm he discovered that the original citation had been incomplete or wrong. He complained particularly about omission of plate numbers.

Footnote references.—Footnotes are expensive and troublesome. Although the article refers to only a few citations, they can be listed at the end. Most footnotes are unnecessary. If you cannot avoid them (we hope you can), type each footnote immediately after the line in which the reference mark occurs, and separate it from the text by lines above and below.

Heading.—If all publications are referred to in the text, head the list "LITERATURE CITED" centered and in capital letters. If the list is more extensive, head it "SELECTED BIBLIOGRAPHY" or "BIBLIOGRAPHY."

Order of items in a citation.—Start the first line of each citation at the left margin and indent subsequent lines. The order of items is as follows:

1. Name of author, followed by a comma. His surname first. If he has only one given name, write it in full; if more than one, use only his initials.
2. Year, followed by a comma.
3. Title, listed exactly as it appears in the original article, followed by a colon.
4. Periodical or series, followed by volume, number, pages, plates, text-figures, and, if necessary for identifica-

tion, the place of publication and the publisher. Serials published by federal agencies should begin "U. S."; by organizations or societies, with the name of the organization or society; and by state organizations, with the name of the state.

Examples of articles published in serials:

ARNOLD, C. A., 1955, A Tertiary *Azolla* from British Columbia: Mich. Univ. Mus. Paleontology Contr., v. 12, no. 4, p. 37–45, 2 pls.

BONNEMA, J. H., 1934, Über die Aufstellung der Schalen der paläozoischen Ostracoden: Zeitschr. Geschiebeforschung, v. 10, p. 80–88.

SPJELDNAES, NILS, 1951, Ontogeny of *Beyrichia jonesi* Boll: Jour. Paleontology, v. 25, no. 6, p. 745–755, pls. 103–104, 3 text-figs.

Examples of articles published as parts of other works:

SOWERBY, J. DE C., 1839, Fossil shells in the lowest beds of the Old Red sandstone, *in* MURCHISON, R. I., The Silurian system, founded on geological researches in the counties of Salop, Hereford, Radnor, and so forth, Pt. 2, Organic remains, p. 602–604, pl. 3: London, John Murray.

STØRMER, LEIF, 1955, Merostomata, *in* STØRMER, LEIF, PETRUNKEVITCH, ALEXANDER, & HEDGPETH, J. W., Chelicerata with sections on Pycnogonida and Palaeoisopus: Treatise on Invertebrate Paleontology, R. C. Moore, editor, Part P, Arthropoda 2, p. 4–41, text-figs. 3–30, Lawrence, Kansas, Univ. Kansas Press and Geol. Soc. America.

Examples of books:

SHIMER, H. W., & SHROCK, R. R., 1944, Index fossils of North America: ix+837 p., 303 pls., New York, John Wiley & Sons, Inc.

ZEUNER, F. E., 1945, The Pleistocene period, its climate, chronology and faunal successions: 322 p., 76 text-figs., London, Ray Soc.

Sequence of citations.—Citations are listed in alphabetical order by the name of the author and chronologically under each author. Publications by the same coauthors are listed as a unit in chronological sequence. After the first listing, use a long dash instead of repeating the author's name or the coauthors' names. If an author has more than one publication in the same year, add "a" after the year in the first citation, "b" in the second, "c" in the third, and so forth.

An example of sequence:

AMI, H. M., 1892, Catalogue of Silurian fossils from Arisaig, Nova Scotia: Proc. Trans. Nova Scotian Inst. Sci., Session of 1891–1892, ser. 2, v. 1, pt. 2, p. 185–192.

BASSLER, R. S., 1915, Bibliographic index of American Ordovician and Silurian fossils, v.1: U. S. Natl. Mus. Bull 92, viii+718 p.

——, & KELLETT, BETTY, 1934, Bibliographic index of Paleozoic Ostracoda: Geol. Soc. America Special Papers, no. 1, xiii+500 p., 24 text-figs.

BONNEMA, J. H., 1913a, De stand der schalen van *Beyrichia tuberculata* Klöden sp.: K. Akad. Wetensch. Amsterdam, Afd. Natuurk., Verslagen gewone Vergad. Wis- en Natuurk., v. 22, p. 117–124, 8 text-figs.

——, 1913b, The orientation of the shells of *Beyrichia tuberculata* Klöden sp.: K. Akad. Wetensch. Amsterdam, Afd. Natuurk., Proc. Sec. Sci., v. 16, p. 67–74, 8 text-figs.

Abbreviations.—Abbreviations are necessary, much as we dislike them, but they need not be coined at random. This journal has appeared in bibliographies and citations variously as J. Pal., Jour. Paleo., and Journ. Paleontol. It should be Jour. Paleontology.

We present only the common words that appear in paleontologic citations. Branches of science are written out, as

Agriculture	Geology	Paleoecology
Archeology	Geophysics	Paleogeography
Astronomy	History	Paleontology
Biology	Hydrography	Petrography
Botany	Hydrology	Petrology
Chemistry	Mathematics	Physics
Ecology	Metallurgy	Sedimentation
Geochemistry	Meteorology	Seismology
Geodesy	Mineralogy	Stratigraphy
Geography	Mining	Technology
		Zoology

Adjectives based on these nouns (words ending in -ic or -ical), however, are abbreviated, as

agr.	geol.	paleoecol.
archeol.	geophys.	paleogeog.
astron.	hist.	paleont.
biol.	hydrog.	petrog.
bot.	hydrol.	petrol.
chem.	math.	phys.
ecol.	metall.	sed.
geochem.	meteorol.	seismol.
geod.	mineralog.	strat.
geog.	min.	technol.
		zool.

Table 1 includes abbreviations of names for various kinds of publications, and Table 2 other words that appear in names of numerous serials containing paleontologic articles.

Abbreviations for units of measurement have been compiled by Duane Roller (1954b), who offers (1954a) suggestions for their use.

TABLE 1—ABBREVIATIONS OF NAMES FOR VARIOUS KINDS OF PUBLICATIONS

aargang	Aarg.
Abhandlung	Abh.
abstract, -s	abs.
Abteilung	Abt.
Acta	
Actes	
afdeeling	afd.
afdeling	afd.
Anales	
Annalen	
Annaler	
Annales	
annals	
année	
anno	
annual	ann.
Anzeiger	Anz.
Arbeiten	Arb.
Årbok	Årb.
Archiv	
Archives	
Archivio	
Årgång	Årg.
Arkiv	
Årsskrift	Årssk.
article	art.
Avdelingen	Avd.
Avhandlingar	Avh.
Band, Bände	
Beilage	Beil.
Beitrag, Beiträge	Beitr.
Bericht	Ber.
Bibliographie	
bibliographic, -al	bibl.
Bibliography	
Bibliothèque	
biennial	bienn.
Bind	
Boletim	Bol.
Boletín	Bol.
Bollettino	Boll.
Bulletin	Bull.
Catalog	Cat.
Catalogue	Cat.
Centralblatt	Centralbl.
chapter	chap.
Circular	Circ.
Communication, -s	Commun.
contribution, -s	contr.
Denkschrift(en)	Denkschr.
Dissertation	Dissert.
document	Doc.
edition	ed.
facsimile, -s	facsim.
fascicle	fasc.
fasciculus	fasc.
Förening	Fören.
Förhandlingar	Förh.
Fortschritte	Fortschr.
Gazzetta	Gazz.
Gazette	Gaz.
handbook	handb.
Handbuch	Handb.
Handlingar	Handl.
Heft	
Jaargang	Jaarg.
Jaarverslag	Jaarv.
Jahrbuch	
Jahresbericht	Jahresber.
Jahresheft	Jahresh.
Jahresversammlung	Jahresvers.
Jahrgang	Jahrg.
Journal	Jour.
Lieferung	Lief.
Magazine	Mag.
Manuscript, -s	Ms., -s
Mémoire	Mém.
Memorandum	Memo.
Memoria	Mem.
mimeographed	mimeo.
Mitteilungen	Mitt.
Monatsbericht	Monatsber.
Monatsheft	Monatsh.
Monatsschrift	Monatsschr.
Monograph	Mon.
monthly	
Neue Folge	
new quarterly series	new quart. ser.
new series	new ser.
number, -s	no., -s
numéro, -s	no., nos.
número, -s	no., nos.
Nummer	Nr.
page, -s	p.
Pamphlet	Pamph.
paper (s)	
part, -s	pt., -s.
proceedings	proc.
publications, -s	pub., -s.
quarterly	quart.
record, -s	rec.
report, -s	rept., -s.
reprint	repr.
Schrift, -en	Schr.
section, -s	sec., secs.
serial	
series	ser.
Sitzungsbericht	Sitzungsber.
Skrift, -er	Skr.
summary	
supplement, -s, -ary	supp.
Teil	
Tidskrift	Tidskr.

TABLE 1—(*Continued*) ABBREVIATIONS OF NAMES FOR VARIOUS KINDS OF PUBLICATIONS

Tidsskrift	Tidsskr.	Verhandlung, -en	Verh.
Tijdschrift	Tijdschr.	Versammlung, -en	Vers.
Tijdskrift	Tijdskr.	volume, -s	v.
tom (Russian)			
tome		Yearbook	
tomus			
transactions	trans.	Zeitschrift	Zeitschr.
translation		Zeitung	
		Zentralblatt	Zentralbl.
Verhandelingen	Verh.	Zhurnal	Zhur.

TABLE 2—ABBREVIATIONS OF WORDS APPEARING IN NAMES OF NUMEROUS PALEONTOLOGIC SERIALS

Academia	Acad.	Delaware	Del.
Académie	Acad.	Department, etc.	Dept.
Academy	Acad.	development	devel.
Accademia	Accad.	District of Columbia	D.C.
Administration	Adm.	distribution	distrib.
Advancement	Adv.	District, -s	Dist.
	A. (in A.A.A.S.)		D. (in District of Columbia)
Akademie	Akad.		
Alabama	Ala.	Division, -s	Div.
Alaska			
allgemeine	allg.	education	
America		educational	educ.
American	Am.	English	
angewandte	angew.	Evolution	
annotated	annot.	examination	exam.
appendix	app.	expedition	exped.
Arizona	Ariz.	experiment	expt.
Arkansas	Ark.	exploration, etc.	explor.
Association	Assoc.	extension	ext.
Advancement	Adv.		
		Faculty	
biographical	biog.	figure, -s	fig., -s.
Biography		Florida	Fla.
Branch	Br.	foraminiferal	foram.
British		formation, -s	fm., -s.
		foundation	found.
California	Calif.	French	
Canadian			
Canadienne		Général, -e	Gén.
Central		generale	gen.
Ciencia (s)	Cienc.	Genootschap	Genoot.
científicas	cient.	Geological Survey	Geol. Survey,
Class (e)	Cl.		GS (with catalog numbers only)
classification	classn.		
collection, -s	coll.	Geologists	
College	Coll.	Georgia	Ga.
Colorado	Colo.	German	
Commission	Comm.	Gesellschaft	Gesell.
Committee	Comm.	Government	Govt.
Company	Co.	Graduate	
Comparative	Comp.		
Conference	Conf.	Idaho	
Congress, etc.	Cong.	Illinois	Ill.
Connecticut	Conn.	illustrated	illus.
Conservation	Conserv.	illustration, -s	illus.
Consolidated		Imperial, etc.	Imp.
Council		Incorporated	Inc.
County		Indiana	Ind.

TABLE 2—(*Continued*) ABBREVIATIONS OF WORDS APPEARING IN NAMES OF NUMEROUS PALEONTOLOGIC SERIALS

information	inf.
Institute	Inst.
Institution	Inst.
internacional	internac.
international, etc.	internat.
introduction	introd.
Investigacion	Inv.
Investigation, -s	Inv.
Iowa	
Island, -s	Is.
Istituto	Ist.
Izvestiya	Izv.
Japanese	
Kaiserlich	K.
Kansas	Kans.
Kentucky	Ky.
Klasse	Kl.
Königlich	K.
Laboratory	Lab.
Library	Libr.
literary	lit.
Literature	Lit.
locality	loc.
Louisiana	La.
Maine	
Maryland	Md.
Massachusetts	Mass.
Meddelanden	Medd.
Meddelelser	Meddel.
Mededeelingen	Meded.
meeting, -s	mtg.
member	mbr.
Michigan	Mich.
Micropaleontologist, The	Micropaleontologist
microscopic, -al	micros.
Midland	
Midwest	
Mijnbouwkundig	Mijnb.
military	mil.
Minas	
Minera	
Minería	
Minero	
Mines	
Minierès	
Minnesota	Minn.
miscellaneous	misc.
Mississippi	Miss.
Missouri	Mo.
Montana	Mont.
Mount	Mt.
Mountain	Mtn.
Mountains	Mts.
Musée	Mus.
Museo	Mus.
Museum	Mus.
Nacional	Nac.
National	Natl.
National Museum	NM (with catalog numbers only)
natural	nat.
Naturales	
Naturalist	
Naturalistes	
Nature	
Naturforschende	Naturf.
Naturforscher	Naturf.
naturhistorisch	naturh.
Naturwissenchaft	Naturw.
naturwissenchaftlich	naturwiss.
natuurkundig	natuurk.
Nebraska	Nebr.
Nederlandsch	
Nevada	Nev.
new	
New Hampshire	N. H.
New Jersey	N. J.
New Mexico	N. Mex.
New York	N. Y.
north	N.
North America	
North Dakota	N. Dak.
northeast	NE
northern	
northwest	NW
Northwest Science	
nouveau, -elle	nouv.
November	Nov.
Novitates	
Observatory	
occasional	
Ohio	
Oklahoma	Okla.
Oregon	Oreg.
Pacific	
paläontologisch	paläont.
peninsula	
Pennsylvania	Pa.
Petroleum	
Philadelphia	Phila.
Philosophical	Philos.
photograph, -s	photo., -s
photographic, -al	photog.
plate, -s	pl., -s.
point	pt.
popular	pop.
preliminary	prelim.
production	
professional	Prof.
progress	
Project	Proj.
Province	
Public	
published	pub.
Railroad	R.R.
Railway	Ry.
research	
resources	res.
review	rev.

TABLE 2—(*Continued*) ABBREVIATIONS OF WORDS APPEARING IN NAMES OF NUMEROUS PALEONTOLOGIC SERIALS

Revista	Rev.
Revue	Rev.
Rivista	Riv.
Rhode Island	R. I.
Royal	
Royale	
Rundschau	
Russian	
Saint, -e	St., -e
Sammlung, -en	Samm.
School	
Schweizerisch	Schweizer.
Science, -s	Sci.
Science (journal)	Science
scientific, -al	sci.
Scientist	
Selskab	Selsk.
Service	
session	sess.
Société	Soc.
Society	Soc.
south	S.
South Carolina	S. C.
South Dakota	S. Dak.
southeast	SE
southern	
southwest	SW
Spanish	
special	
species	sp.
State	
Station	Sta.
study, -ies	
subspecies	subsp.
supply	
synonym	
table, -s	
technic, -al	tech.
Tecnica	
Técnico	
temperature	
temporary	
Tennessee	Tenn.
Tennessee Valley Authority	TVA
Territory, -ies, -ial	Terr.
Territory of Hawaii	T. H.
Texas	Tex.
topographic, -al	topog.
Township, -s	T., Tps.
Trudy	
und	u.
undetermined	undet.
United States	U. S.
United States Geological Survey	USGS (only if followed by number)
United States National Museum	USNM (only if followed by number)
University, etc.	Univ.
Universelle	Univ.
Union of Soviet Socialist Republics	U.S.S.R.
Utah	
Verein	Ver.
Vermont	Vt.
versus	vs.
Vetenskaps	Vetensk.
Vetenskapsakademins	Vetenskapsakad.
Videnskabernes	Vidensk.
Videnskaps	Vidensk.
Virgin Islands	V. I.
Virginia	Va.
Washington	Wash.
west	W.
West Virginia	W. Va.
western	
Wetenschappen	Wetensch.
Wisconsin	Wis.
Wissenschaft, -en	Wiss.
Wochenschrift	Wochenschr.
Wyoming	Wyo.

REFERENCES IN TEXT

In the text, reference is made in parentheses to author, year, and specific pages or illustrations. If (as rarely happens) the entire article is referred to, only the author and year are necessary. To refer to original publication of a species, enter the year, pages, and illustrations in parentheses after the author of the species, as in *Signetopsis quadrilobata* Henningsmoen (1954, p. 62–63, pl. 7, figs. 1–9, pl. 8, fig. 25).

Some examples of references:

It has been suggested (Hessland, 1949, p. 127) that frills may have served as runners. . . .

Triebel (1949, p. 210) says that the muscle scars in Candoninae differ from those in the closely related subfamily Cyclocypridinae.

In 1954 (p. 29) Henningsmoen revised his previous (1953, p. 238) assignment of *Kloedenia*. . . .

The fauna of the Windom shale has been described by Stover (1956).

SYNONYMY

A synonymy serves an important purpose. It is a contracted history of the taxon as interpreted and evaluated by the writer. Because it is contracted, however, each part must be accurate and in standard format.

Each scientific name in the synonymy should be entered once. It can be followed by references to all authors who have used

it for the taxon being considered. The first entry should be the first name used, and subsequent names should follow in chronological order of their appearance.

References in synonymies should be handled like those in the text, except that parentheses need not be used. Synonymies containing complete citations are unnecessarily long (and unnecessarily expensive), and those containing no titles and only cryptic strings of "illegal" abbreviations and initials to indicate the journal or book are difficult to use. References should be to author, year, pages, and illustrations, with full citations of publications in Literature Cited. This method is a sensible compromise between economy and clarity.

An example of synonymy in the recommended form:

Beyrichia sussexensis WELLER, 1903, p. 253, pl. 23, figs. 3,4.
Beyrichia perinflata WELLER, 1903, p. 254, pl. 23, figs. 6.
Kloedenia sussexensis ULRICH & BASSLER, 1908, p. 302, pl. 38, figs. 19,20. BASSLER & KELLETT, 1934, p. 366. SWARTZ & WHITMORE, 1956, p. 1064–1065, pl. 106, figs. 7–12.

LITERATURE CITED

R(OLLER), D(UANE), 1954a, On symbols for units of measurement: Science, v. 120, no. 3130, p. 3A.
——, 1954b, Symbols for units of measurement: Science, v. 120, no. 3130, p. 1078–1080.

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 673, MAY 1957

PALEONTOLOGICAL NOTE

NEW RECORDS OF LEPTOCHOERIDS FROM THE LATE OLIGOCENE AND EARLY MIOCENE OF SOUTH DAKOTA

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During the summer of 1955 a jaw fragment (SDSM 5573) of *Nanochoerus* sp. was found in the late Oligocene Poleslide member of the Brule formation by M. R. Dawson. The locality (SDSM V5411) is located on the Bloom Ranch in Shannon County, South Dakota. Macdonald (1955) indicated that the range of *Nanochoerus* was from Chadronian through Orellan. This specimen extends the range to the latest Whitneyan as it was collected from just below the contact of the Poleslide and the basal ash of the overlying Arikaree beds.

In 1956 another jaw fragment (SDSM 56101) was found by the author in slightly younger beds a few miles to the south, along the Porcupine Creek drainage. This fragment, which is referable to *Leptochoerus* sp., was collected from a nodular zone just above the basal ash of the Arikaree beds. The locality (SDSM V5354) is illustrated in Osborn (1918, figure 7) where this level is designated as being part of the Upper Brule Leptauchenia Zone. This designation is incorrect as a rich early Miocene microfauna has been collected from this level. The occurrence of this genus in these deposits extends the known range of the Leptochoeridae into the early Miocene.

REFERENCES

MACDONALD, J. R., 1955, The Leptochoeridae: Jour. Paleont., vol. 29, p. 439–459, pl. 46–47, 9 text-fig.

OSBORN, H. F., 1918, Equidae of the Oligocene, Miocene, and Pliocene of North America, Iconographic Type Revision: Am. Mus. Nat. Hist. Mem., vol. 2, p. 1–330, pl. 1–44, 173 fig.

MANUSCRIPT RECEIVED OCTOBER 15, 1956

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 674–676, MAY 1957

NOMENCLATURAL NOTES

NEW NAMES FOR SPECIES OF *BAIRDIA* AND *AMPHISSITES*[1]

CHALMER L. COOPER
U. S. Geological Survey, Washington, D. C.

The careful, detailed work of I. G. Sohn, of the U. S. Geological Survey, has revealed that three trivial names used by me for Pennsylvanian and Mississippian ostracodes of Illinois are synonyms. Therefore, the following names are assigned to these species.

BAIRDIA ACULEALA, new name

Bairdia aculeata COOPER 1941, Illinois Geol. Survey, Rept. Inv. 77, p. 24, pl. 1, fig. 47,48, Kinkaid formation, Mississippian, Illinois.
Not *Bairdia aculeata* BONNEMA, 1940, Naturh. Maandbl. vol. 29, no. 10, p. 108, pl. 3, fig. 9–14. Cretaceous, Holland.

BAIRDIA ANGUSTATA, new name

Bairdia angusta COOPER, 1946, Illinois Geol. Survey, Bull. 70, p. 41, pl. 1, fig. 41–44. Seville limestone, Lower Pennsylvanian, Illinois.
Not *Bairdia angusta* (Münster). JONES, 1849, Monogr. Entomostraca Cretaceous formation England: Palaeontogr. Soc. London, p. 26, pl. 6, fig. 18a–f.
part = *Pontocypris bosquetiana* JONES & HINDE, 1890, Palaeontogr. Soc. London, p. 4, pl. 2, fig. 65, pl. 4, fig. 3.
part = *Bythocypris reussiana* JONES & HINDE, 1890, ibid., p. 12, pl. 2, fig. 56, 61–63.
part = *Bythocypris silicula* (Jones). JONES & HINDE, 1890, ibid., p. 13, pl. 2, fig. 64, pl. 3, fig. 27–30.
Not *Bairdia angusta* SARS, 1866, Norske Videnskabs-Selskabet, Forhandl. (1865), p. 22. = *Macrocypris sarsi*: Müller, 1912.

AMPHISSITES CARINODUS, new name

Amphissites carinatus COOPER, 1946, Illinois Geol. Survey, Bull. 70, p. 97, pl. 15, fig. 15–18,21,22. Bogota and Woodbury formations, Upper Pennsylvanian, Illinois.
Not *Amphissites carinatus* COOPER, 1941, Illinois Geol. Survey, Rept. Inv. 77, p. 48, pl. 9, fig. 19–21.

[1] Published with permission of the Director, U. S. Geological Survey.

MANUSCRIPT RECEIVED SEPTEMBER 22, 1956

GEOGRAPHIC RANGE OF *TYTTHODISCUS* EXTENDED TO ALASKA

W. WALOWEEK AND W. L. NOREM
Shell Oil Company, Los Angeles, California
and
California Research Corporation, La Habra, California

Several specimens of the microfossil genus *Tytthodiscus* were found recently in rocks presumably of Miocene age from southern Alaska. Previously the genus had not been found outside of California (Norem, 1955).

The species *Tytthodiscus californiensis* Norem was found in the Miocene part of the Yakataga and the Miocene Puffy member of the Katalla formations in the Yakataga and Katalla districts, respectively, of Alaska. The stratigraphic range of this species in California extends from the middle Eocene into the Pliocene.

Tytthodiscus chondrotus Norem also occurs in the Puffy member of the Katalla formation. The range of this species in California appears to be restricted to the lower Miocene.

According to D. J. Miller of the U. S. Geological Survey (personal communication, September 6, 1956) definite age assignments are not possible because both the Alaskan formations "appear to span epoch boundaries and both involve uncertainties of correlation with the west coast standard section and in turn with the European standard section." The Yakataga formation is classed as Miocene and Pliocene (?). Miller states also that the Katalla formation "will be designated as Oligocene and Mio-

cene in reports in preparation." The Puffy member is considered to be of Miocene age.

The authors are indebted to the Standard Oil Company of California for the samples and stratigraphic information.

REFERENCE

NOREM, W. L., 1955, Tytthodiscus, a new microfossil genus from the California Tertiary: Jour Paleon., vol. 29, p. 694–695.

MANUSCRIPT RECEIVED OCTOBER 1, 1956

THE GENUS *FENESTELLA*

NILS SPJELDNAES
Paleontologisk Institutt, Oslo

Recently Elias (1956) has redescribed some Silurian fenestrellids as a part of an attempt to reestablish the generic name *Fenestella* Lonsdale according to the Rules of Zoological Nomenclature. All students of Paleozoic bryozoans heartily agree with him in this, but some formal objections must be made against some points in his paper.

The generic name.—*Fenestella* Lonsdale, 1839 (Bryozoa) is a junior homonym of *Fenestella* Bolten, 1798 (mollusca). Both names were changed to *Fenestrella:* Bolten's name by Gray, 1848, and Lonsdale's by d'Orbigny, 1850. It is disputable whether these changes were misprints or nom. nov. (cf. Neave, vol. II, p. 403; Toots, 1951, p. 235).

The type species.—The type species of *Fenestella* Lonsdale, 1839, is *Gorgonia antiqua* Goldfuss, 1829 (non[?] *Retepora antiqua* Goldfuss, 1826), and was selected by King, 1850. According to the studies of Toots (1951, p. 237), the type specimen of this species is lost, and it is impossible to recognize it from the descriptions and figures. It is therefore necessary to supress King's selection, and select a new type species.

Two species have been proposed as new type species. The first one, *F. plebeia* McCoy is a Carboniferous one. Since most of the fenestellas are from the Carboniferous, and are important for the stratigraphy of that period, this would probably be a good choice for the type species. The disadvantages are that the type specimens are not redescribed, and that the species was not originally included in *Fenestella* by Lonsdale, 1839.

The other species proposed, *F. subantiqua* (d'Orbigny, 1850) was also not included in the original description of the genus, being probably a nom. nov. for *Fenestella antiqua* Lonsdale, non *Gorgonia antiqua* Goldfuss. Even if this is the species which Lonsdale intended to refer to *Fenestella*, it does not formally belong to the species originally included in the genus.

By the description given by Elais (1956) this species is well known, even if it seems to be broadly defined, including also *F. patula* McCoy, 1850. By a combination of misprints in Elias' paper (p. 317), it appears as if *patula* (cited as McCoy, 1850) has priority over *subantiqua* (cited as d'Orbigny, 1852). In fact both names were published in 1850 (as correctly stated in the list of references given by Elias). In the original description of *patula* (McCoy 1850, p. 288) *F. subantiqua* is mentioned, indicating that it is the older one of the two names.

It is not quite clear from the very brief text in d'Orbigny, 1850, if he regarded *subantiqua* as a nom. nov. for *antiqua* Lonsdale, 1839, non Goldfuss, 1829, or if he regarded Lonsdale's determination of the species to be correct, but realized that *Fenestella* ("*Gorgonia*") *antiqua* Goldfuss, 1829, was a junior homonym of *Fenestella* ("*Retepora*") *antiqua* Goldfuss, 1826, and that *subantiqua* is a nom. nov. for Goldfuss's species, and not for that of Lonsdale. This doubt is an argument against the use of *subantiqua* as a type species of *Fenestella*.

Two of the species originally included in *Fenestella*, *F. milleri* and *F. prisca* are type species of other fenestrellid genera, and can not be used for *Fenestella*.

Nobody seems to have discussed the possibility of using the last of the four original species included in the genus, *Retepora reticulata* Hisinger, 1837, as the type species. In contrast to the statement of McCoy (1850, p. 289) this species is easily recog-

nized, and it is redescribed by Hennig (1906). It is probably conspecific with the specimens refered to this species by Lonsdale, and with *F. reteporata* Shrubsole. This species differ from most others of the genus in the mode of formation of the fenestrules (cf. Elias, 1956, p. 329).

It is an important question which of these species should be selected as the new type species. Either the Rules must be followed as far as possible, even if it will mean an extention of the present diagnosis of the genus (*F. reticulata* approaches *Septopora* in the formation of the fenestrules), or the new type species should cover exactly the present concept of the genus, disregarding the priority of the originally mentioned species.

In the latter case, I think it would be better to select a Carboniferous species, since most species of *Fenestella* are from the younger Paleozoic, where they are of considerable stratigraphic importance. Even if *F. subantiqua* resembles the younger species, one must expect that future studies on the internal structures might reveal important differences, which might restrict *Fenestella* to the Silurian. In this case the whole procedure for preserving the generic name will be in vain. I am therefore inclined to regard that *Retepora reticulata* Hisinger, or better *Fenestella plebeia* McCoy should be selected the new type species of *Fenestella*.

REFERENCES

BASSLER, R. S., 1935, Fossilium Catalogus, Animalia part. 67: p. 1–229. s-Gravenhage.

ELIAS, M. K., 1956, A revision of *Fenestella antiqua* and related Silurian fenestrellids: Jour. Paleont., vol. 30, p. 314–332, pl. 43.

HENNIG, A., 1906, Gotlands Silur-Bryozoer 2: Arkiv for Zoologi, vol. 3, no. 10, p. 1–62, 7 pl. Stockholm.

HISINGER, W., 1837, Lethæa Svecica seu Petrificata Sueciæ Iconibus et Characteribus Illustrata: p. 1–124, 38 pl. Holmiae (Stockholm)

NEAVE, S. A., 1939–1950, Nomenclator Zoologicus: vol. I–V. London.

TOOTS, H., 1951, Über einigen cryptostome Bryozoen aus dem Mitteldevon des Rheinischen Schiefergebirges: Neues Jahrb. Geol. Paläont. Abh., Bd. 93, p. 233–246, pl. 14–15.

References to the other papers mentioned are found in these papers.

MANUSCRIPT RECEIVED JULY 24, 1956

CORRECTION

QUANTITATIVE TRILOBITE STUDIES I. ERRATA

ALAN B. SHAW
Shell Oil Company, Denver, Colorado

THE following errors have been noted in the article cited (Shaw, 1956):

(1) p. 1211, 2d column, 10th line from bottom. For "valve" read "value."

(2) p. 1215, 2d column, first line under heading "Coefficient of Correlation." For "aeditional" read "additional."

(3) p. 1216, 1st column, formulae just above Table 3. Strike out "mm." in both.

(4) p. 1220, 2d column, 4th and 5th lines from bottom. Formulae should read:

$$l_1 = 0.815 + (t_{.01})\ (0.1263)$$
$$l_2 = 0.815 - (t_{.01})\ (0.1263)$$

SHAW, A. B., 1956, Quantitative trilobite studies I. The statistical description of trilobites: Jour. Paleontology, v. 30, p. 1209–1224, 2 figs., 9 tables.

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 677, MAY 1957

NOTICES

THE FUTURE OF ARID LANDS

Edited by: Gilbert F. White, Department of Geography, The University of Chicago. 6×9 inches, 464 pages, 49 illustrations, index, clothbound, 1956. Price $6.75. AAAS Members' prepaid order price $5.75. A symposium volume of the American Association for the Advancement of Science. British Agents—Bailey Bros. & Swinfen, Ltd., 46 St. Giles High Street, London.

Representatives from 28 countries met to consider the present state of research and development on arid zone problems and to formulate recommendations for new lines of research. Leaders from 17 of these countries gave papers at the symposium in Albuquerque, New Mexico, and joined in the Conference at Socorro, New Mexico, in formulating a series of recommendations. The symposium papers and the 31 Conference recommendations are reproduced in this volume.

The symposium sessions were developed around a few basic questions. The representation and treatment of the subjects were highly interdisciplinary and led to some important conclusions. The breadth and scope are indicated by the groupings of the Conference recommendations: Anthropology, Archaeology and Geography; Meteorology and Climatology; Hydrology, Geology and Soils; Biology, Ecology and Conservation; Organization, Communication, and Interdisciplinary Programs. Workers in all these fields, as well as administrators of government and private programs, will find the contents of this volume both stimulating for ideas and an invaluable source of information.

THE ZOOLOGICAL RECORD

The object of the Zoological Record is to give, by means of an annual volume, complete lists of the works and publications relating to zoology in all its branches that have appeared during the year preceding the issue of the volume, together with a subject and systematic index.

The complete volume can be obtained from the Society at the price of £6 0s. 0d. per volume.

In addition to the complete bound volume, the separate sections (including sections on Comprehensive Zoology, individual phyla or smaller groups, and a list of new genera and subgenera) may be obtained singly, bound in printed paper covers.

The Paleontological Society has for several years made a small grant in support of this publication, because of its great value to all paleontologists. A copy of the annual volume should be in the library of every Paleontology Department, and members may wish to purchase separate sections, which are modestly priced (about 50 cents to $1.50 each). Address all communications to the Director and Permanent Secretary, Zoological Society of London, Regent's Park, London, N.W.1, England.

PALEONTOLOGICAL SOCIETY OF INDIA

About 150 copies of the inaugural number of the Journal of the Paleontological Society of India are for sale. Anyone interested in obtaining a copy please write to Dr. M. R. Sahni, Paleontological Society of India, 27, Chowringhee, Calcutta 13, India.

JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 3, P. 678, MAY 1957

SOCIETY RECORDS AND ACTIVITIES

In accordance with Article 3, Chapter 1 of the By-Laws of the Paleontological Society, the Secretary submits the following nominations for membership in the Society. The list has been approved by the Council of the Society.

ANGOLD, DONALD W., Department of Geology, University of British Columbia, Vancouver, B.C.: Robert G. Greggs, V. J. Okulitch.

BOYD, DONALD WILKIN, Geology Department, University of Wyoming, Laramie, Wyo.: Marshall Kay, John Imbrie, Norman D. Newell.

GLEN, WILLIAM, Department of Paleontology, University of California, Berkeley, Calif.: Knoxie C. DeLise, Joseph H. Peck, J. Wyatt Durham.

HAY, WILLIAM W., 804 W. Charles, Champaign, Illinois: Harold W. Scott, Harold R. Wanless.

HENNINGSMOEN, GUNNAR, Paleontologisk Museum, Sarsgaten 1, Oslo 45, Norway: Walter C. Sweet, A. K. Miller, W. M. Furnish.

KLAPPER, GILBERT JOHN, Department of Geology, Kansas University, Lawrence, Kansas: Walter Youngquist, Edward Zeller.

SCHAEFFER, KATHERINE MAUDE MARIE, Geology Department, Washington Univ., St. Louis, Mo.: H. N. Andrews, Jr., Arthur B. Cleaves, Dorothy Jung Echols.

SPJELDNAES, NILS, Paleontologisk Museum, Sarsgaten 1, Oslo 45, Norway: L. Størmer, Walter C. Sweet.

SWANSON, RICHARD WAYNE, Department of Geology, Univ. of Nebraska, Lincoln, Nebr.: Walter Sadlick, John P. Howe.

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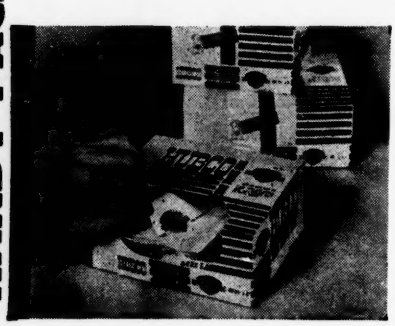

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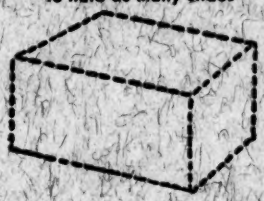

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